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UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Industrial property protection and technological innovation

A case study of the United Republic of Tanzania

UNITED NATIONS

Distr.
GENERAL

UNCTAD/ITP/TEC/17
24 January 1991

ENGLISH ONLY

Industrial property protection and technological innovation

A case study of the United Republic of Tanzania

Study prepared by S.M. Wangwe
at the request of the UNCTAD secretariat

GE.91-55105/2897B

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FOREWORD

(i) The Committee on Transfer of Technology, in section V, paragraphs 15 and 16 of its resolution 28 (V), requested the UNCTAD secretariat, in co-operation with other institutions concerned, to "continue its valuable studies of policies and instruments on the promotion and encouragement of technological innovation in all countries, and particularly in developing countries, taking into account the comments and views expressed at the fifth session of the Committee". According to the same resolution, the secretariat's studies should, inter alia, consider the influence which the following factors may have in promoting and creating an innovative environment:

(a) Risk-taking in a changing, innovative environment;

(b) Incentives required at all levels of society, including those provided by systems of industrial property protection; and

(c) Linkages, including feedback mechanisms, between research and development activities reflecting practical local endowments and conditions.

(ii) The present study has been prepared in response to subparagraph (b) above and in pursuance of resolution 32 (VII) of the Committee on Transfer of Technology. It is a part of a wider research programme of the secretariat and focuses on the effectiveness of incentive schemes for promoting innovation. Besides the present study, a case study on the use of patents for the protection of technological innovation in selected Swedish firms has been prepared by the secretariat as well as two studies dealing with incentives other than the industrial property system: one on Spain and one on France.

(iii) The main purpose of the study is to assess the role of industrial property protection in the promotion of technological innovation in the United Republic of Tanzania. For the purpose of the study, industrial property protection is generally used to indicate the exclusive rights granted under the patent system and the incentive effect they might have on innovative activity, while innovation is taken to refer to the first introduction of new products and processes on a commercial scale into the market.

(iv) In order to understand the system under which industrial property protection is operating or is supposed to be operating in Tanzania, chapter I presents the existing and the recently enacted patent system in Tanzania. Chapter II analyses the actual practice of patenting in Tanzania in terms of number of patents granted and their distribution among different industries. Chapter III examines the industrial property protection system from the point of view of enterprises and some technological institutions. The analysis of the expected impact of industrial property protection on innovative activity is made on the basis of the responses obtained from a sample of 18 enterprises and research institutions.

(v) The study was prepared by Professor Samuel Wangwe of the University of Dar es Salam at the request of the UNCTAD secretariat.

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Chapter I

THE INDUSTRIAL PROPERTY PROTECTION SYSTEM IN TANZANIA

1. For the purpose of this study, both the outgoing patent system and the new patent system of the United Republic of Tanzania will be analysed. The outgoing system has been operating under the Patents Registration Ordinance (Cap. 217) of 1931 (revised in 1962). This system is described briefly in section A. The new system established under the Patent Act No. 1 of 1987 is described in section B.

A. The outgoing patent system

2. The outgoing patent system was based on the Patents Registration Ordinance (Cap. 217) of 1931. Under this Ordinance a patent is granted to the applicant provided the applicant pays the stipulated fees, describes what is to be patented and shows evidence that the applicant was granted the same patent in the United Kingdom not more than three years from the date of the application. In essence, Tanzania's patent system was fully pegged to the United Kingdom system and could not be characterized as an independently operating system. The requirement that the invention/innovation first be registered in the United Kingdom made it difficult for the public authorities to use the patent system to encourage domestic innovative activity and created an unnecessary roundabout for foreign applicants who might have registered their patents in countries other than the United Kingdom. This patent system is still operating in the country but arrangements are under way to begin implementing the new patent system for Tanzania, enacted in 1987.

B. The new patent system

3. The recently enacted patent system is contained in Patent Act No. 1 of 1987, which is meant to repeal and replace the Patents Registration Ordinance (Cap. 217) of 1931. The main objective of the new Act is to make better provision for the promotion of inventiveness and innovation, for the facilitation of the acquisition of technology on fair terms through the grant and regulation of patents, utility certificates and innovation certificates. The detailed regulations and operational procedures governing the use of Patent Act No. 1 of 1987 are in the process of being worked out. Since it should be operative soon, the main features of the Act are presented in the following sections.

1. Functions

4. The functions of the Patent Office should be:

(a) To grant patents;

(b) To promote inventiveness among nationals of Tanzania;

(c) To establish and operate a patent documentation centre for the purpose of dissemination of information on patents;

(d) To collaborate with other bodies whether local or foreign, whose functions relate to patent matters;

(e) To provide information on patented technology so as to facilitate transfer and acquisition of technology by Tanzania; and,

(f) To perform such other functions as are necessary for the furtherance of the objects of the Patent Act.

2. Patentability

5. An invention is patentable if it is new, involves an inventive step and is industrially applicable. In this context an invention is new if it bears the novelty attribute in that it is not anticipated by prior art. An inventive step involves an invention which would not have been obvious to a person skilled in the art on the date of the filing of the application. An invention is industrially applicable if it can be made or used in the technological sense in any kind of industry.

3. Right to patent

6. The Act stipulates that the right to patent belongs to the inventor and that inventions made in execution of commission or employment shall belong to the employer. However, it also provides for the working out of an equitable remuneration between employer and employee taking into account the importance of the invention and any benefit derived from the invention by the employer.

4. Term of patent

7. The Act states that the patent shall expire at the end of the tenth year after the date of the filing of the application. The term of the patent may be extended for a period of five years.

5. Contractual licences

8. The Act establishes the rights of the licensees and those of the licensor and lays down the prohibited terms in licence contracts.

6. Compulsory licences

9. The Act stipulates that compulsory licences may be issued for non-working or for unsatisfactory working, for interdependent patents or for products deemed of vital importance.

7. Utility certificates

10. An invention, the Act states, is eligible for a utility certificate if it is new and industrially applicable. Utility certificates may be granted even if the invention falls short of novelty. An examination as to substance need not be carried out before a utility certificate is issued.

Chapter II

THE PATENT SYSTEM IN PRACTICE

11. Patenting in Tanzania is still operating on the basis of the Patents Registration Ordinance (Cap. 217), which should have been repealed by the Patent Act No. 1 of 1987. Thus up to the end of 1989 the Patent Office was granting patents following the Patents Registration Ordinance (Cap. 217). For this study a sample of three years was selected (i.e. 1980, 1985 and 1987) and the patents granted during these years were analysed in respect of source of applications and types of industries for which the patents were granted.

A. Patents granted

12. The number of patents granted over the 1980-1987 period is presented in table 1. It is clear that the number of patents granted in Tanzania is very small compared to the numbers granted in the more developed economies. The number of patents registered peaked at 93 in 1980 and recorded a low figure of 16 in 1985.

Table 1

Number of patents granted: 1980-1987

Year	Number of patents
1980	93
1981	41
1982	30
1983	56
1984	37
1985	16
1986	45
1987	21

Source: Patent Office, United Republic of Tanzania.

13. The patents registered during the sample years are all foreign as shown in table 2. Eighty per cent of all the patents registered during the period under review originated from four countries: the United States, the United Kingdom, the Federal Republic of Germany and Switzerland. It is notable that patents owned by nationals of third world countries account for only 3 per cent of all patents registered in 1980, 1985 and 1987.

Table 2

Patents by nationality

Nationality	1980	1985	1987	Total	%
India	1	0	0	1	0.8
Italy	3	0	0	3	2.3
United Kingdom	20	6	2	28	21.5
Switzerland	16	5	6	27	20.8
Japan	1	1	0	2	1.5
United States	24	3	6	33	25.4
Sweden	1	0	0	1	0.8
France	5	0	0	5	3.8
Canada	1	0	0	1	0.8
Hungary	3	0	1	4	3.1
Belgium	2	0	0	2	1.5
Germany, Fed. Rep.	14	1	2	17	13.1
Bahamas	1	0	0	1	0.8
Australia	1	0	2	3	2.3
Zimbabwe	0	0	2	2	1.5
	93	16	21	130	100

Source: Patent Office, United Republic of Tanzania.

14. The absence of Tanzania-owned patents is rather striking. However, it was found that, since the inception of the system, only one Tanzania-owned patent has been registered in Tanzania while two have been registered in Sweden and three have been registered in the United Kingdom. Presumably this is a reflection of the fact that the patent system was not meant to encourage innovators and inventors in Tanzania. The recently enacted patent system is expected to correct this defect.

B. Types of industries patented

15. The patents registered in Tanzania in 1980, 1985 and 1987 are predominantly chemical industry based, as shown in table 3. The group of chemical industries accounts for about 84 per cent of all patents registered. Within the chemical industry, pharmaceuticals are dominant followed by agricultural chemicals. The category referred to as instrumentation is also chemical-industry-related as these inventions/innovations appear to be owned by the chemical industry. These instruments are largely apparatus which go along with or facilitate the manufacture of various chemical compounds.

Table 3

Patents granted by sector: 1980-1987

Sector	1980 Number	%	1985 Number	%	1987 Number	%	Total Number	%
Mechanical engineering	2	2.2	0	0	0	0	0	1.5
Industrial chemicals	5	5.4	0	0	1	4.8	6	4.6
Agricultural chemicals	15	16.1	5	31.3	5	23.8	25	19.2
Pharmaceuticals	56	60.2	10	62.5	12	57.1	78	60.0
Instrumentation	5	5.4	1	6.2	0	0	6	4.6
Metal products	2	2.2	0	0	0	0	2	1.5
Food and beverages	3	3.2	0	0	1	4.8	4	3.1
Building materials	5	5.4	0	0	2	9.5	7	5.4
Total	93	100	16	100	21	100	130	100

Source: Patent Office, United Republic of Tanzania.

16. These patents are largely held by transnational corporations which are mainly importing the products into the country while manufacturing is located elsewhere. Most of those which have set up production facilities are mixing various chemicals while the manufacture of the compounds is taking place abroad.

17. Most of the patents belong to technology-based enterprises. The industries involved in the patenting activity seem to be technologically dynamic as evidenced by the fact that many patents are improvements and inventive steps over the previous registrations.

Chapter III

INDUSTRIAL PROPERTY PROTECTION: A VIEW FROM THE LOCAL ENTERPRISES

18. The prevalence of foreign-owned patents and the striking absence of local firms in the patents register calls for a closer look at innovation in Tanzania and an analysis of the views and attitudes of entities involved in it.

19. In order to examine the patent system from the point of view of enterprises and other entities (including R & D institutions) actually operating in Tanzania a sample of 18 firms was selected. The firms selected for study are engaged in a variety of industrial activities as shown in table 4. The sample consists of 15 firms from 6 different industries and 3 local R & D institutions (see table 5). All the R & D institutions are publicly owned while the other 15 enterprises are mainly private (10) and the rest (5) are public owned.

Table 4

The nature of firms/enterprises surveyed

Main activity	Number of
Chemical industry	3
Soap and detergents	1
Textile and garments	1
Leather products	1
Metal working	6
Food and beverages	3
Technological research and development institutions	3
Total	18

Table 5

Ownership pattern of sample enterprises

Foreign	3
Local private	7
Public	8
Total	18

A. Awareness of the patent system

20. The study investigated the extent to which the local firms are aware of the local patent office as a first step towards making use of its services. As shown in table 6 about 56 per cent of all the enterprises were not aware of the existence of the patent office. All the three local R & D institutions were aware of the patent system, probably because it is mentioned in the Acts establishing the institutions. All the foreign enterprises were aware of the patent office but did not make use of its services. These findings reinforce the earlier observation that the patent office was set up not so much to serve local innovative efforts as to serve foreign innovators in Tanzania. It is hoped that the recently enacted patent system will redress this anomaly.

Table 6

Awareness of the patent office

Institutions' awareness	Number of enterprises/institutions
1. Aware of it since establishment of the enterprises/institution	5
2. Institutions which became aware of it subsequently	3
3. Not aware at all	10
Total	18

B. Types of innovations

21. In studying the 18 sample firms, information was sought on the type of innovations actually taking place or which have been carried out recently. This information is important in facilitating an assessment of the extent to which the patent system could cater for the type of inventions which are actually being carried out in the country.

22. The types of innovations which are actually carried out in the sample firms are shown in table 7. These are primarily minor modifications (about 44 per cent of the firms) and production of spare parts to replace originally imported parts (in another 22 per cent of the firms). In 28 per cent of the firms major innovations consist of substitution of locally available inputs for imported inputs (e.g. locally available vegetable oils in place of imported oils). These are hardly likely to qualify for granting of patents. The only category of innovations which could be granted patents are those relating to the design of new equipment. There are only two firms engaged in such activities out of the 18 interviewed for this study. Yet, the results of such activities would have to be subjected to patent examination to determine whether they qualify for patenting or not.

Table 7

Nature of innovations actually carried out recently

Type of innovation	Number of firms/institutions
1. Minor modifications to the production formulae or of imported technology	7
2. Imitating spare parts	4
3. Designing of equipment	2
4. Use of local inputs as substitutes for imported inputs	5
Total	18

23. However, the findings on the nature of innovations actually taking place suggests that most of them may not be patentable. This implies that in order to encourage innovative activity starting from the present low level of technological innovation it will be necessary to reward the minor innovations through less demanding awards like utility certificates or through incentive mechanisms other than patents.

C. Adopting innovations from other sources

24. One function of the patent system is to provide information about available technologies and in the process encourage adoption of technologies developed by others. In the field survey the extent of adoption of technological innovations made by other institutions or firms was investigated. The findings indicated that two R & D institutions (TEMDO 1/ and TIRDO 2/) had successfully disseminated five innovations to enterprises which were now operating them on commercial scale. These technological innovations are a centrifugal water pump, a maize sheller, an oil expeller, a sugar cane crusher, and a grain cleaner and thresher.

25. This technology transfer was paid for in various forms. In some cases the proceeds from commercial sales were shared between the adopter and the innovator, and in other cases the adopter paid a lump sum of money to cover for the rest of the design and costs of transferring the know-how.

26. Overall however, the incidence of technological diffusion among enterprises was very low. In this context, the field-work also revealed that there was no formal system for disseminating information about technological innovations and improvements. From the findings on the limited technological diffusion among enterprises, it appears that the patent system or other systematic mechanism for the dissemination of technological information would play an important role.

D. Methods of protection in use

27. In the near absence of an effective patent system the question which arises is how do firms protect whatever innovations they make. In the field survey this question was asked and the findings are shown on table 8. The four firms which are already granted patents under the Patents Registration Ordinance of 1931 (with minor revisions in 1962) reported that they use the patents to protect their innovations. Among the four firms only one was local and it had negotiated for a licence for a patent which is owned by a firm registered and operating in the United Kingdom. Most enterprises (44 per cent) used trade marks on their products. However, most of such firms admitted that they were using fairly standard and known technology and that there was not much unique technology in the process for producing their products. Trade marks were used as a means of safeguarding against poor quality imitations and maintaining uniform product quality.

Table 8

Methods used to protect innovations

Method used	Number of firms
Patenting	4
Trade marks	8
Secrecy	1
None	5
Total	18

28. When asked to indicate which methods of industrial property protection the firms would prefer, 14 firms responded. The responses indicate that patents were ranked among the top two methods by 57 per cent of the respondents, followed by registered designs (43 per cent) and trade marks (36 per cent) and secrecy (29 per cent). Taking the top three preferences again the leading preferred methods are patents (71 per cent) and registered designs (71 per cent), followed by trade marks (43 per cent) and secrecy (43 per cent).

E. System of rewarding innovators

29. The system of patents is only one of various methods of rewarding innovators; there may be other means. At firm level, the field survey addressed itself to this question. Out of the 18 firms, 7 had some system (formal or informal) of rewarding innovators. In most cases, however, the arrangements were rather ad hoc and not systematically incorporated in the activities and schemes of the enterprises.

30. At national level the Tanzania Award for Scientific and Technological Achievement (TASTA) is given to individuals or institutions in recognition of their achievements in the application of science and technology to the socio-economic development of the country. The aim of the Award is to encourage creativity and initiative for greater scientific and technological

achievements and to foster the utilization of such achievements for the purpose of promoting and accelerating socio-economic development of the country. TASTA has been administered under the Tanzania National Scientific Research Council, which has now been upgraded to the National Science and Technology Commission.

31. The reward for technological innovation through TASTA covers very few awards. In a year two or three awards only may be given out. In order to qualify for the award, the achievement must represent a scientific or technological invention, discovery, innovation or adaptation. The payment given depends on the importance of the innovation. Being annual, this award has not really been internalized in the daily operations and decision-making of individuals and institutions. It cannot be a substitute for a system which rewards innovators as innovations are carried out. Moreover, the magnitude of the TASTA awards is small (in the range of $US 500-2,000), which is not enough to recover a substantial part of costs of research and development.

Chapter IV

SUMMARY AND CONCLUSION

32. This study set out to examine the role of industrial property protection in the promotion of technological innovation in Tanzania.

33. The existing patent system is based on the Patents Registration Ordinance (Cap. 217) of 1931 (revised in 1962). Under this Ordinance, registration of a patent is granted to the applicant provided the applicant pays the stipulated fees, describes what is to be patented and shows evidence that the applicant was granted the same patent in the United Kingdom not more than three years from the date of the application. In essence, Tanzania's patent system has been fully pegged to the United Kingdom system and cannot be said to be operating independently.

34. The recently enacted patent system is contained in Patent Act No. 1 of 1987, which, once it is implemented, will repeal and replace the Patents Registration Ordinance (Cap. 217) of 1931 (revised in 1962). The main objective of the new Act is to make better provision for the promotion of inventiveness and innovation, and for the facilitation of the acquisition of technology on fair terms through the grant and regulation of patents, utility certificates and innovation certificates.

35. Patenting in Tanzania has up to now been on the basis of the Patents Registration Ordinance (Cap. 217). The Patent Office continues to grant patents on the basis of the outgoing Patents Registration Ordinance (Cap. 217).

36. The number of patents granted over the period 1980-1987 is presented in table 1. It is clear that the number of patents granted in Tanzania is very small compared to the numbers granted in the more developed economies. The number of patents registered peaked at 93 in 1980 and recorded a floor figure of 16 in 1985.

37. Four countries account for over 80 per cent of all the registered patents. It is notable that patents owned by nationals of third world countries account for only 3 per cent of all patents registered in 1980, 1985 and 1987.

38. The absence of Tanzania-owned patents is rather striking. Presumably this is a reflection of the fact that the patent system was not meant to cater for Tanzanian innovators and inventors since an applicant had to register in the United Kingdom as a pre-condition for being granted a patent in Tanzania.

39. The patents registered in Tanzania in 1980, 1985 and 1987 are predominantly chemical industry based. Within the chemical industry pharmaceuticals are dominant followed by agricultural chemicals.

40. These patents are largely owned by transnational corporations which are mainly importing the products into the country while manufacturing takes place abroad.

41. About 56 per cent of the enterprises interviewed for this study were not aware of the existence of the Patent Office. All the foreign enterprises were aware of the Patent Office and had made use of its services. These findings reinforce the earlier observation that the Patent Office has so far mainly served foreign enterprises and foreign patent owners.

42. The innovations which are actually performed in Tanzania are primarily minor modifications to already existing inventions (about 44 per cent of the firms) and production of spare parts to replace originally imported parts (in another 22 per cent of the firms). In 28 per cent of the firms the substitution of locally available inputs for imported inputs is considered as a "major" local innovation (e.g. locally available vegetable oils in place of imported oils). However, these are hardly likely to qualify for granting of patents.

43. The findings on the nature of innovations actually taking place suggests that most of them may not be patentable. This implies that in order to encourage innovative activity starting from the present low level of technological innovation it will be necessary to reward the minor innovations through less demanding awards like utility certificates or through incentive mechanisms in addition to patents.

44. The incidence of technological diffusion among enterprises was very low. In this context, the field-work also revealed that there was no formal system of disseminating information about technological innovations and improvements.

45. Out of the 18 firms, 7 had some system (formal or informal) of rewarding innovators. In most cases, however, the arrangements were rather ad hoc and were not systematically incorporated in the activities and schemes of the enterprises.

Notes

1/ Tanzania Engineering and Manufacturing Design Organization.

2/ Tanzania Industrial Research and Development Organization.

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Printed at United Nations, Geneva
GE.91-55105
March 1991 - 3,870

United Nations publication

UNCTAD/ITP/TEC/18

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Historical trends in protection of technology in developed countries and their relevance for developing countries

UNITED NATIONS

Distr.
GENERAL

UNCTAD/ITP/TEC/18
26 December 1990

Original: ENGLISH

Historical trends in protection of technology in developed countries and their relevance for developing countries

Study prepared by Dr. Alberto Bercovitz-Rodriguez
at the request of the UNCTAD secretariat

GE.91-55014/2742B

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FOREWORD

The present study has been prepared by Dr. Alberto Bercovitz-Rodriguez at the request of the UNCTAD secretariat in the context of the secretariat's on-going programme of work on the economic, commercial and developmental aspects of industrial property protection. The latest UNCTAD resolution relevant to this work is resolution 32 (VII) of the Committee on Transfer of Technology, which invites the UNCTAD secretariat to continue its work on the economic, commercial and developmental aspects of the industrial property system in the transfer of technology to developing countries.

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INTRODUCTION - NATIONAL INTERESTS AND PATENT LAW

1. With the passage of time, patent law has undergone a major change which is affecting the very function of patents. Since it is on this function that patent legislation must be based, it is clearly important not only to analyse the objectives pursued by patent legislation, but also, more particularly, to identify the factors determining the direction of its change.

2. The present study seeks to demonstrate that the function of patents, and therefore of patent legislation, has been and still is determined basically by the technological and industrial interests of the country enacting the legislation. This principle has some important consequences which may be summarized as follows:

(a) Patent law does not imply the existence of rules to govern patents which must be the same everywhere and at all times. On the contrary, there is a large variety of options in this area and legislation adopted by different countries at different times may therefore differ on essential points;

(b) Patent law may undergo substantial changes in any given country, to adapt it to that country's changing interests in the technological and industrial fields; and,

(c) The content of patent law may vary among countries, especially when their interests in the technological and industrial fields differ.

Chapter I

SOME ASPECTS OF THE EVOLUTION OF PATENT LAW IN THE COUNTRIES OF WESTERN EUROPE

A. Protection of inventors and introducers 1/

3. In Europe, the birthplace of patent law, patents arose as an instrument for promoting and encouraging technological and industrial progress in the country granting them, without regard either to the interests of the actual inventor or of those of other countries. The aim pursued was the introduction into the national territory of new technology and its industrial exploitation there. Initially, therefore, no distinction was made between patents of invention and patents of importation. All patents were patents of importation, although they were purportedly granted to persons called inventors. Whether or not the invention had been previously known abroad was of no significance. What mattered was that it should be unknown in the country granting the patent.

4. In England, for example, although the Statute of Monopolies of 1623/4 provided for the granting of patents "to the true and first inventor" or inventors, a person who merely introduced an invention into the country was regarded as this true and first inventor. The traditional English doctrine recognized this, affirming as it did, for example, that the purpose of patent law was to encourage the development of new local industries, which was why the introducer of an invention was always treated as the "true and first inventor". 2/ As late as 1893, the judicial ruling given in the case of Moser v. Marsden 3/ confirmed that the holder of the patent was the true and first inventor within the meaning of the patent law, whether he actually invented or whether he merely imported a foreign invention.

5. The same concept - that the introducer of the invention into the country was the inventor - is also to be found in the first French patent law, the Decree of the National Constituent Assembly of 31 December 1790 (7 January 1791 by modern reckoning) concerning the authors of useful discoveries. Article 1, paragraph 3, provides as follows: "Whoever first imports into France a useful discovery shall enjoy the same advantages as if he had been its inventor". However, paragraph 9 of the same article provides that "the utilization of patents granted for a discovery imported from a foreign country may not extend beyond the period fixed in that country for its utilization by the first inventor". 4/

6. There was thus a transition from complete equivalence between inventor and introducer to a distinction between patents of invention and patents of importation. The latter, granted to those who merely introduced into the country inventions known abroad, persisted in France up to the Act of 5 July 1844, and continued in Spain until they were abolished by the new patent act of 20 March 1986.

B. Absolute and relative novelty

7. Until recently, in many European countries the standard of novelty required for the patentability of an invention was far from being absolute and depended to a large extent on the perceived usefulness of the invention for local industry. For example, the British Patents Act of 1949, which remained

in force until it was replaced by the new Patents Act of 1977, required only that the invention should be new in the United Kingdom (section 32.1.(e)). Likewise, in the Federal Republic of Germany, inventions were not required to have absolute novelty in order to be patentable until the enactment of the patent law of 16 December 1980. According to the previous legislation of 2 January 1968, an invention was not considered new only "if, at the time of the application, it has already been described in such a fashion in publications printed within recent years, or has already been used in the country in such a widely known manner, that utilizaton of the invention by others experienced in the field seems possible" (section 2). This meant that the novelty of an invention was not impaired either by printed publication dating from more than a hundred years before or by examples of utilization of the invention that had occurred abroad or were not widely known about within the country. Nowadays, in the States members of the European Community, a requirement of absolute novelty has been imposed as one of the consequences entailed by the establishment of European patents, (which were instituted by the Convention of Munich on the Grant of European Patents, of 5 October 1973).

C. Exploitation of patents within the national territory 5/

8. In European countries, it was for a long time a priority objective of patent law to ensure that the inventions patented in the country were actually exploited within the national territory. Patents were in fact devised as incentives for the development of new industries in the patent-granting country. It was generally believed that the privilege granted would be of no value to the country unless it was locally exploited.

9. However, with the growth in international trade, it was realized that enterprises could benefit from a patent grant without having to exploit the patented invention in the country granting it, but by importing from abroad the products protected by the patent. The response of national legislation to this practice was to establish that the use of a patent as an import monopoly would constitute a ground for forfeiture of the patent. For example, the French Act of 5 July 1844 established as a ground for forfeiture of a patent the fact that its holder had imported into France articles manufactured abroad which were similar to those protected by the patent (art. 32, para. 3). In the United Kingdom, section 27 of the Patents Act of 1907 provided that a patent could be revoked if the holder exploited it exclusively or principally abroad. A similar provision, but of more restricted application, was maintained in the successive Patent Acts of 1919, 1928 and 1932. A similar reasoning was also followed in Germany leading to the adoption of the patent laws of 1877 and 1881 (specifically para. 11 of these laws). 6/

10. Similarly, failure to exploit the patented invention within the national territory constituted a ground for forfeiture of the patent under the earliest legislation on the subject. In France, article 16 of the Decree of the National Constituent Assembly of 31 December 1790 (7 January 1791 by modern reckoning) concerning the inventors of useful discoveries stipulated that: "Any inventor who, within two years of the date of granting of the patent, has not put his discovery into effect and has given no good reasons for his inactivity shall be divested of his patent". In Spain, too, article 24 of the Royal Decree of 14 October 1820 likewise provided that "the inventor, improver or introducer shall cease to be considered as proprietors if they let two years elapse without putting into operation their invention, refinement or improvement".

11. In short, during the 19th century and the first half of the 20th century not only was it obligatory to exploit the patent, on pain of its losing its validity, but it was also forbidden, subject to the same penalty, to utilize the patent as a means of securing an import market for one's products. However, since then, the legislation of most of these countries has undergone a radical change. The provisions prohibiting the utilization of a patent as a means of securing an import monopoly, have been replaced by new ones which confer on the holder of the patent, as one of his basic entitlements, the exclusive right to import the products obtained through the patented invention. 7/

12. This change of position has, moreover, been reflected, to some extent, in the Paris Convention for the Protection of Industrial Property, through whose successive revisions this evolution may be observed. The original wording of 20 March 1883 provided for the obligation to exploit the patent within the country, but also contained a provision establishing that the importation of patented products was not in itself a ground for forfeiture (art. 5). In the Washington revision of 2 June 1911, the possibility of forfeiture for non-working was still further limited. The patent could be forfeited only for failure, without good reason, to exploit locally the patent within three years from the date of filing of the application for it (art. 5, second para.).

13. In the revision adopted at the Hague on 6 November 1925, forfeiture on the grounds of non-exploitation was made conditional upon the prior granting of a compulsory licence, and although the time during which it could remain unexploited without good cause was maintained at three years, it was counted from the date of granting of the patent (art. 5, second, third and fourth paras.). In the London revision of 2 June 1934 it was stipulated that compulsory licences for failure to exploit the patent could be granted only for non-working without legitimate reasons for three years from the date of granting of the patent, and that forfeiture could be declared only after a lapse of two years from the granting of the first compulsory licence (art. 5A). Finally, the revision adopted at Lisbon on 31 October 1958, which is still in force, introduced a technical improvement in the wording of article 5A, specifying in addition that the time which must elapse before compulsory licences were granted was four years from the date of application for the patent or three years from the date of its granting, whichever period last expired, and that a compulsory licence for failure to exploit could not be exclusive, nor be transferred independently of the enterprise or part thereof exploiting the licence granted.

Chapter II

THE INDUSTRIAL PROPERTY PROTECTION OF CHEMICAL AND PHARMACEUTICAL INVENTIONS 8/

14. Of particular significance in the evolution of European legislation on the protection of industrial property is the history of protection of chemical and pharmaceutical inventions, notably under German patent law. The developments that have occurred in this area are of interest for a number of reasons. First, particular importance is attached in many countries to the problems posed by the protection of chemical and pharmaceutical inventions and international debate on this issue has not yet been exhausted. Secondly, much attention has always been paid in this area to the German legal system, with regard both to its legislation and jurisprudence and, more particularly, to its doctrinal basis. Thirdly, an analysis of the developments in this sector provide a striking example of how certain rules that originate for the clear purpose of protecting industrial production on the national territory come at a later stage to be used as an instrument for securing export monopolies.

A. The patentability of substances and processes

15. As is well known, German legislation prohibited the patenting of inventions of new chemical and pharmaceutical substances until the prohibition was abolished by the Patents Act of 4 September 1967. For nearly a century prior to that - from the enactment of the first patent law on 25 May 1877 - only inventions of chemical and pharmaceutical production processes could be patented. Section 1 (para. 2, sub-para. 2) of the Act of 1877, which was carried over into successive patent acts until its deletion in 1967, excluded from patentability: "Inventions of foods, stimulants and medicaments, as also of substances produced by chemical means, provided that the inventions do not concern a specific process for the manufacture of the products". The reasons invoked in support of the ban on patenting medicaments was similar to the one that has been used in other countries, namely, concern to obviate difficulties in obtaining medicines or unwarranted price rises that might result from a monopoly. Another aim was also to obviate possible abuse of patents in advertisements in order to promote sales of medicaments.

16. The justification provided for prohibiting by law the patenting of inventions of substances obtained by chemical means is also of particular significance. In the original Bill (for the Act of 1877) it was laid down that inventions of foods, stimulants and medicaments could not be patented, but there was no provision against patenting chemicals. It was in fact a petition submitted to Parliament (the Reichstag) in March 1877 - two months before the promulgation of the Act - by the Board of Directors of the Deutsche Chemische Gesellschaft (German Chemical Company) which prompted the inclusion of the prohibition in the Act. 9/ The petition contained the following passage:

> "With regard to the granting of patents for chemical inventions, the principle should be maintained that it is solely and exclusively the method of manufacture of a chemical product that can be the subject of the patent, and not the product itself." This suggestion was justified

> as follows in the petition: "A chemical product can be obtained by various methods and from different starting materials; the grant of a patent for the product itself would prevent better processes discovered subsequently from being brought into effect in the interest of the public and of the inventors."

The prohibition was thus introduced to promote the development of the chemical industry by stimulating process inventions rather than product inventions.

17. Years later, in studying the draft revision which was to result in a new Act (of 7 April 1891), the German chemical industry maintained its opposition to the patentability of chemical substances. Thus, at the general meeting of the Association for the Protection of the Interests of the German Chemical Industry, held at Bremen in 1890, it was stated in the report prepared by the Patents Committee that the Committee, in studying the draft revision, had considered and rejected the possibility of making a substance patentable. "Such comprehensive protection", said the report, "has, however, always been considered by the German chemical industry as an obstacle prejudicial to the discovery of new and improved processes and has been energetically opposed". 10/

18. As mentioned above, this prohibition was maintained until the Act of 4 September 1967 abolished it, somewhat unexpectedly and largely in response to some peculiar arguments. The amendment was not provided for in the Government's draft and was introduced by the Law Committee of the Bundestag. 11/ Basically, the argument adduced was that applicants for patents for inventions of substances which were not legally patentable tried to patent all the imaginable manufacturing processes with a view to achieving a virtual monopoly over the substance. This manner of proceeding resulted in an excessive workload for the Patents Office (Patentamt). Hence, it was argued, the removal of the prohibition would lighten the work of the Patentamt, and that was precisely the basic purpose of the new Act. 12/ In addition to these arguments, it was asserted that the prohibition was no longer justified in the present state of the German economy, and also that it was not admissible under the European Convention for the unification of Certain Features of Patent Law, signed by the Federal Republic of Germany.

19. It appears that the underlying reason for this change in German legislation was the changed circumstances of the chemical industry. At the beginning of the century, in view of the limited knowledge that existed in major sectors of chemistry, the large chemical firms could achieve a monopoly of new substances by patenting all the imaginable processes for obtaining them, since it had the necessary means for conducting this kind of research. Nowadays, knowledge in the chemical field has increased to such an extent that it is no longer possible to patent all the diverse processes for obtaining a given product, so the only way for the large firms to secure a monopoly over new substances is to allow patentability of the substance itself. Moreover, since, owing to the necessary concentration of research facilities, inventions of new substances take place almost exclusively in the large firms, they have been able in this way to secure a strengthened position in the market for themselves. 13/

B. The scope of protection afforded by patents for chemo-pharmaceutical production processes

20. Other well-known rules - those extending the scope of protection of the process patent to the product directly obtained, and the rule shifting the burden of proof so that it must be shown, when a substance is new, that it has been obtained by a process different from the one patented - appear to have also been established to protect the German chemical industry vis-à-vis imports of chemical substances produced abroad, specifically in Switzerland.

21. Initially, German jurisprudence interpreted in a strict sense the provisions prohibiting the patenting of inventions of substances obtained by chemical means, ruling that the process patent did not confer an exclusive right to market the product obtained by the patented process when that product had been imported from abroad. This interpretation had some negative effects on the German industry since, taking advantage of the non-patentability of chemical inventions in other countries, especially Switzerland, factories were set up in these countries to exploit processes patented in Germany, notably for the manufacture of synthetic dyes, in order then to export the products obtained to the German market. The process patents did not give the German industrialists any legal means for preventing the import of such products. 14/

22. The Association for the Protection of the Interests of the German Chemical Industry took steps to deal with the problem as early as 1879 at its Congress held in Baden-Baden, where it adopted by a large majority a resolution stating:

> "The meeting considers that the term subject of the invention should be held to mean not only a patented product, but also any product that has been manufactured by a patented process." 15/

23. The question was not however resolved. Therefore, in 1885, in pursuance of a decision taken at the General Meeting in Heidelberg, the Association addressed a petition to the Chancellor of the Reich asking him to adopt measures for instituting effective protection of the holders of German chemical patents against foreign competition and also asking him to organize an enquiry into the effects of the Patents Act on the chemical industry and the amendments that would be desirable to the Patents Act in the interests of that industry. 16/ The situation was considered so serious that in 1886 the Association of German Synthetic Dye Factories (Vereinigung Deutscher Teerfabriken) asked the Chancellor of the Reich for an immediate change to be made through an emergency law. 17/

24. The upshot of these demands was the inclusion of two new provisions in the Patents Act of 7 April 1891. The following sentence was added to Section 4: "If the patent has been granted for a process, its effects extend also to products strictly obtained by that process". Another change made was the inclusion in Section 5, paragraph 2 of the clause called "shifting of the burden of proof", which provided that "if the subject of the invention concerned is a process for the manufacture of a new substance, it shall be considered, failing proof of the contrary, that any substance having the same characteristics has been manufactured by the process patented".

25. Satisfaction was thus given to the demands which were put forward to protect the German chemical industry and whose object was that the exploitation of production process inventions by firms in German territory should not have to face competition from substances imported from abroad, more particularly from Switzerland. To afford the German industry still further protection, a trade agreement was signed early in the century with Switzerland exempting from customs duties aniline and other dyes imported into Germany from Switzerland. However, Germany reserved the right to demand payment of customs duties for chemical products "if Switzerland had not amended before 31 December 1907 its legislation on patents so as to provide that articles of the class referred to and their like or the processes for their manufacture should be patentable where the invention was a new one". 18/

26. In furtherance of the provisions of this agreement, and taking into account the need to protect, to the fullest extent compatible with it, the Swiss chemical industry, the new Swiss Act of 21 June 1907 firstly established the patentability of chemical processes, and secondly, so as to reduce to a minimum the effects of that patentability, stipulated that patents for inventions of manufacturing processes for chemical substances could cover only a single process starting from strictly defined substances and leading to a single end-product. It was thus made extremely difficult - to the advantage of the Swiss chemical industry - to protect chemical inventions, since the Act prohibited the usual practice of patenting a series of processes. 19/

Chapter III

RECENT TRENDS IN LEGISLATIVE PRACTICES AND REASONS UNDERLYING THEM

A. The significance of recent trends

27. The way in which the patents system has evolved in the countries of Western Europe reflects the changes gradually introduced into the system through a long period, as the economic and technological level of those countries changed. Whereas the system was originally designed as a means of fostering the technological and industrial progress of the State granting the patent, with economic self-sufficiency in view, there has been a continuous trend towards "internationalizing" its functions so as to enable owners of inventions to exploit them not only at the national but also at the international level. In short, the trend has moved away from patent legislation devised for and suited to the strictly national market towards legislation which will facilitate the exploitation of the protected inventions on the international market.

28. It is this trend which underlies the changes described above. The grant of the right to hold a patent only to the inventor and not to the introducer, and the insistence on absolute novelty at the world level, have tended to result in all patents for a given invention belonging to the same inventor. At the same time, the notable weakening of the obligation to work the patent in the country granting it has facilitated the exploitation of the patented invention in a number of national markets through imports rather than through local production. This has in turn led to patents being utilized for securing exclusive rights over export markets. Moreover, rules such as those extending the protection of the patented manufacturing process to the product directly obtained by that process or those on the reversal of the burden of proof for patents concerning processes that result in new products, which were originally devised to protect national industries by blocking imports, came to be used for the strengthening of exclusive import rights and thus for the promotion of exports.

B. Analysis of the background to the trend

29. The reasons for this trend are obvious. In an initial phase, patents were used in European countries as a means for achieving industrialization and technological progress in the country granting the industrial property rights. It is important to note that this phase broadly coincided with the industrial revolution in Europe. At a later stage, steps began to be taken to make it increasingly easy for the technology generated by firms within the country itself to be also exploited abroad on the international market. In other words, once the country had succeeded in acquiring a technological potential that needed to be exploited on a wider market than the national one, the rules of patent law were placed at the service of this new policy.

30. This shift was, of course, made inevitable by far-reaching changes that have had and are continuing to have major repercussions upon markets and upon the generation and dissemination of technology. The remarkable improvements in transport and communications and in production systems have contributed to

the globalization of markets. Manufacturing no longer has to be undertaken locally; on the contrary, it is far more profitable to have a single production centre from which to supply extensive geographical areas belonging to different States - sometimes indeed to supply the entire planet. Moreover, the internationalization of markets is matched by that of firms, which have become multinational.

31. At the same time, technological research is becoming ever more expensive and its results, once made public, are disseminated very rapidly throughout the world. A number of important consequences follow from these developments. The first is that research can be cost-effective only if its results are exploited at the international level. The second is that the only way to make that exploitation profitable is to make it exclusive, which means that patents are needed since, without them, the new technologies, in view of their rapid dissemination, can be copied. And lastly, account must be taken of the fact that the pursuit of profitability will generally preclude exploitation of the technology at the production level from taking place in all the countries where it is planned to market the products obtained.

C. The new functions of patents at the international level

32. Patent legislation in the developed countries of Europe - and of almost all other developed countries - is increasingly being used today to promote technological progress and to facilitate the exploitation of inventions throughout the world. Obviously, the various national laws enacted in pursuance of this global objective cannot in themselves ensure its attainment, precisely because they are national. To achieve the end sought, Governments are trying to elaborate, or further strengthen, legal instruments with international scope, among which particular mention must be made of the Paris Convention for the Protection of Industrial Property, the Patent Co-operation Treaty (PCT), signed at Washington in 1970, and the Convention on the European Patents, signed at Munich in 1973. The last two are intended to facilitate the securing of patents for the same invention by a single patentee in a number of different countries, and their provisions therefore include the requirement of absolute novelty and the grant of the patent rights to the inventor.

33. For its part, the Paris Convention is subject to increasing strains resulting from the new orientations of patent laws in developed countries. The Paris Convention originated, and long remained, an instrument in whose application the developed countries played a major role. The principle of national treatment enshrined in the Convention was considered appropriate, in view of the similar tenor of the national laws. However, with the increasing concern for facilitating exploitation of patented inventions at the international level, modifications were introduced into the Convention so as to strengthen national legislative provisions on such matters as priority for Union countries or the obligation to exploit the patent. There is also a clear tendency among developed countries to increase the unifying and harmonizing role of the Convention, which has so far been limited. Such an approach would, however, be ill-suited to the circumstances of the less developed countries, whose fundamental interest is to stimulate their industrial and technological progress and, for this purpose, preserve their freedom to adapt their industrial property régime to their economic needs.

34. There is thus a growing tension between two different concepts of the function of patents, representing two different phases in the evolution of patent laws. The developed countries view patents as an instrument for technological competitiveness at world-wide level, whereas the developing countries assign to them the same objective as did the developed countries themselves at a prior stage in their industrial development, namely the stimulation of national technological and industrial progress. Thus, while the developed countries are seeking to universalize rules specific to their own patent law at the current stage of development, developing countries are trying to maintain the same rules that were in force in the developed countries at earlier stages. This is the logical consequence of their differing levels of economic and technological development. These differences will undoubtedly mark the future evolution of patent legislation, both domestically and internationally.

Notes

1/ See A. Bercovitz, "Patentes de introducción" in the Nueva Enciclopedia Jurídica, Editor F. Seix (in press).

2/ See Halsbury's Laws of England, Second Edition under the general editorship of the Right Honourable the Viscount Hailsham, Vol. XXIV, Butterworth & Co., (Publishers), Ltd., London 1937, p. 583, No. 1111. See also a similar statement in the same work, p. 561, No. 1071.

3/ Ibid., p. 583, n.(in fine), citation of L.J. Lindley.

4/ For text of this decree see DUVERGIER, J.B. Collection Complète des Lois. Décrets, Ordonnances, Réglements et Avis du Conseil d'Etat, Paris, A. Guyot et Scribe, Librairie-Editeurs 1824, Vol. II, p. 158 F (specifically p. 159).

5/ See A. Bercovitz, "La obligación de explotar las patentes y la reforma del derecho de patentes español", in La obligación de explotar las patentes en España y en Iberoamérica, Ed. Montecorvo, Madrid 1978, pp. 371 F.F. (specifically pp. 371-379).

6/ See Joachim Bussmann, Die patentrechtliche Zwangslizenz, Franfurt-am-Main (1975), p. 31.

7/ On this point see, for example, the French Act of 13 July 1978 (art. 29), the British Act of 1977 (section 60) or the Spanish Act of 1986 (art. 50).

8/ See A. Bercovitz "La patentabilidad de las invenciones farmacéuticas", in A. Bercovitz (ed.) La protección jurídica de las invenciones y la industria químico-farmacéutica, E. Montecorvo, Madrid 1974, pp. 124 F.F. (specifically pp. 178-192 and 218-222).

9/ See texts reproduced in von Kreisler, GRUR 1951, pp.534 and 535; PECHMANN, GRUR 1957, p. 264; Hermann Schwanhausser, Stoff und Verfahrensschutz chemischer Erfindungen, Carl Heymanns Verlag KG, Köln-Berlin-Bonn-München 1962, p. 35; Paul A. Zimmermann, GRUR 1966, pp. 539 F.F. (specifically p. 540) and by the same author, Patentwesenin der Chemie (Ursprünge, Anfänge, Entwicklung), Badische Anilin & Sodafabrik AG, Ludwigshafen-am-Rhein 1969, p. 36.

10/ See von Kreisler, op. cit. (footnote 8 above) p. 534 and R. Weidlich, GRUR 1951, p. 551.

11/ See Karl Nastelski in Eduard Reimer, Patentgesetz und Gebrauchsmustergesetz (Systematischer Kommentar), 3 erweiterte Auflege, Carl Heymanns Verlag KG, Köln-Berlin-Bonn-München 1968, p. 127, para. 1, note 91. The report can also be found in Albrecht Krieger, Das neue Patent und Warenzeichenrecht, Carl Heymanns Verlag KG, Köln-Berlin-Bonn-München 1968, pp. 186 F.F. (specifically pp. 197 F.F.).

12/ It must be borne in mind that the reform was aimed above all at changing the procedure so as to expedite the granting of patents, since in 1966 there was a backlog of 271,000 applications awaiting examination. See Althammer, GRUR 1967, p. 394. See also Bercovitz "Nuevas leyes de patentes en Francia y en la República Federal de Alemania", Revista de Derecho Mercantil No. 108 (1968), pp. 309 F.F.

13/ See Klaus Brunne, Chemiepatente, VEB Deutscher Verlag für Grundstoffindustrie, Leipzig 1968, pp. 98-100.

14/ See Hans-Gunther Eggert, GRUR 1964, p. 592; Jörg Hahn, Der Schutz von Erzeugnissen patentierter Verfahren, Carl Heymanns Verlag KG, Köln-Berlin-Bonn-München 1968, pp. 13/14 and von Kreisler, op. cit. (footnote 8 above), p. 536.

15/ For text see Zimmermann, GRUR 1966, p. 541 and, by the same author, op. cit. (footnote 8 above) Patentwesen ..., p. 36. Hahn, op. cit. (footnote 13 above), p. 14.

16/ See Zimmermann, Patentwesen ... (cited in footnote 8 above) p. 39. The petition is also mentioned by Hahn, op. cit. (footnote 13 above), p. 14, and von Kriesler, op. cit. (footnote 8 above), p. 536.

17/ See Zimmermann ... (cited in footnote 8 above), p. 39.

18/ See R. Weidlich Blum, Das schweizerische Patentrecht, Verlag Stämpfli & Cie., Bern 1934, Vol. I, p. 116.

19/ See R. Weidlich Blum, op. cit. p. 117 and "A propos de la revision de la loi suisse sur les brevets" in La propriété industrielle, 1906, pp. 119 F.F. (specifically p. 120).

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Printed at United Nations, Geneva
GE.91-55014
January 1991 -3,100

United Nations publication

UNCTAD/ITP/TEC/19

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Technology indicators and developing countries

UNITED NATIONS

Distr.
GENERAL

UNCTAD/ITP/TEC/19
22 January 1991

ENGLISH
ENGLISH, FRENCH AND SPANISH ONLY

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Technology indicators and developing countries

Study prepared by the UNCTAD secretariat

GE.91-55080/2906B

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PREFACE

This report has been prepared pursuant to resolution 32 (VII) of the Committee on Transfer of Technology whereby the UNCTAD secretariat was requested, "drawing on the work carried out by other international organizations, to prepare a list of internationally comparable technological indicators in wide use, including methodology and explanatory notes". The study has been prepared with the assistance of Dr. Bernadette Madeuf-Michalet.

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Chapter I

INTRODUCTION

1. There is growing concern among policy-makers and academics about the role of technology in trade and development. The rapid pace of technological change has stimulated a renewed interest in technology issues, and efforts have been undertaken to develop indicators which permit an assessment of countries' scientific and technological capacities and the monitoring and evaluation of related progress and performances.

2. For more than 25 years now, there have been continuing efforts by both national administrations and international organizations to produce new and improve existing technology indicators. From the Frascati Manual by OECD, which provides guidelines for collecting and presenting data on resources devoted to research activities, to recent discussions on how statistical instruments could be adapted to measure the interrelationship between science, technology and economic performance, the interest has concentrated mainly in the more technologically advanced countries.

3. For developing countries, UNESCO has taken the lead in collecting information on scientific activities and human resource development. A number of other international organizations collect, on a regular basis, information which is of relevance for the construction of technology indicators (WIPO on patent activities; UNIDO on industrial statistics; IMF on balance of payments; World Bank on social development indicators; UNSO on trade statistics). 1/ However, this information is collected for other purposes and its value and usefulness for technological activities have not yet been appraised.

4. The absence of an integrated information system on technology-relevant information on developing countries is a serious constraint for constructing and applying technology indicators. Besides data limitations, the construction of technology indicators for developing countries is complicated by conceptual deficiencies as it is not clear whether or to which extent indicators as developed and applied in OECD countries are adequate for developing countries.

5. Developing countries vary greatly in their experience of industrialization and the usefulness of established technology indicators may also vary according to the levels of development or industrialization policies. There is little empirical evidence that would shed some light on these issues. Discussions on the role of technology in developing countries have been mostly confined to the firm level, with emphasis on the newly industrialized countries, and there is no coherent approach to assess the role of technology at the macro level. 2/

6. This report attempts to remedy this deficiency by providing an interpretation of technology indicators in terms of issues relevant to developing countries. The focus is on internationally comparable indicators which can be constructed on the basis of internationally published data sources. At country or industry level, more specific indicators could be constructed as the actual level of development and policy strategies, as well as different data sources, could be taken into account. However, there is a need first to provide a more general framework of technology indicators which may serve as a reference for further elaboration.

Chapter II

THE ANALYTICAL FRAMEWORK

A. The nature of technology and technological change

7. The presentation and discussion of technology indicators needs to be based on a understanding of the meaning of "technology" and "technological change". In recent years, numerous empirical and theoretical studies have contributed to a better understanding of technological change, thus challenging traditional views on technology. 3/ The predominant focus of these contributions has been on technologically leader countries. Although this does not invalidate the conceptual understanding of technological change in general, it leaves open many questions concerning the importance of technology features specific to developing countries.

8. Technology, broadly defined as the application of knowledge to produce goods and services, involves the dynamic interaction of human skills, physical assets, and organizational and institutional settings. This very broad definition calls for a more detailed explanation to highlight some important features of technology. Technology is not a form of "information", that has the properties of being costly to produce but virtually costless to transfer and use. On the contrary, technological knowledge is often tacit (i.e. cannot be codified in the form of instructions) and is mostly specific to firms and to particular products and processes. Technology involves a fundamental learning aspect, characterized (Nelson and Winter (1982)) by varying degrees of opportunity, appropriability and cumulativeness.

9. Opportunity stems from the scope of technical opportunities and the easiness with which technological advance can be achieved for a given effort. Appropriability relates to the capability of firms to internalize economic benefits, which in turn is influenced by learning curves, lead times and industrial property protection. Cumulativeness refers to the mostly incremental advance of the knowledge base.

10. Technological change as a process does not correspond to the formerly accepted linear model wherein scientific knowledge gives rise to technical innovation. This "science push" model was relying on assumptions relative to the scientific sourcing of techniques and the existence of successive and distinguishable phases from science to industrial applications. On the other hand, the "demand-pull" model is not accepted either. In this model the rate and direction of innovations were determined by economic activity, and more specifically by the demand for capital goods. It is now recognized that the process of technological change includes complex interdependencies among the various stages of innovative activity where the supply of technology and the demand for technology are interrelated. Moreover, there are considerable variations among sectors, products and technologies in the rate, direction, and determinants of technological change.

B. Implications for measurement

11. The general features of technology and technological change outlined above have important implications for the measurement and interpretation of technology indicators.

12. First, indicators measure only aspects of technology rather than particular bodies of knowledge. Thus, they may reflect elements of science and technology, such as human resources, physical assets, organizational settings or the economic and legal environment, but they do not cover the entire constellation of the elements which constitute technology. Accordingly, there is no unique or superior indicator. Each has its strengths and weaknesses and for the purpose of analysis a range of indicators needs to be adopted.

13. Secondly, the cumulative and firm-specific character of technological change implies that technological strengths of firms and countries do not change rapidly over time. This means that technological patterns and trends in the recent past are a reliable guide to events in the not too distant future. It also means that some comparisons of levels and composition of "technological accumulation" across regions and countries (Patel and Pavit (1988)) are possible.

14. Thirdly, while easy to specify in principle, each indicator involves many thorny research issues. For example, what operational definitions should be used for counting scientists and engineers? Should it be by their formal degrees, their current work activity? Or, in what sense do patents reflect rates of technical innovation?

15. Fourth, due to the complex and multidimensional interactions between the different elements of technology, it is difficult to trace causalities among technology indicators. Moreover, in view of the dynamic nature of technological change, the relative importance of technology indicators varies not only across industries and countries but also over time. Thus, technological change is not synonymous with physical capital accumulation, or scientific advances, even if it overlaps with both of them.

16. Fifth, additional data constraints in developing countries, regarding availability and quality of technology-relevant information suggest the consideration of an even broader range of technology indicators than those used for developed countries.

17. Sixth, the relative importance of individual indicators and their interpretation varies according to the level of development and differences in economic policies of countries. Technical assistance, for example, is a major source of technology for least developed countries while for higher income developing countries it is of little relevance. Similarly, a growing inflow of capital goods or foreign direct investment may be interpreted as increased availability of technology or as a growing dependency on foreign technology.

C. Classification of technology indicators

1. General criteria for classification

18. Different criteria can be applied for classifying technology indicators depending on the purpose and level of aggregation of the analysis.

19. One type of classification which takes into account the process-character of technological change distinguishes three broad categories of indicators: input indicators, which measure the resources devoted to the generation of scientific and technological knowledge; output indicators, which measure the

outcome of scientific and technological activities; and technology-related indicators of economic performance which are used for assessing the effect of technology on economic performance. This type of classification appears suitable for both technologically-advanced, as well as developing countries, because the basic features of the process are the same across countries, although different indicators may need to be used to take into account differences among countries in levels of development and industrialization policies.

20. Another set of criteria for classifying technology indicators aims at discerning basic components of technology in the form of (UN (1988)):

(i) Object-embodied technology;
(ii) Person-embodied technology;
(iii) Document-embodied technology;
(iv) Institution-embodied technology.

21. Interpreting technology as a combination of hardware and software is useful to better conceptualize various forms of technology. However, at the aggregate level it appears difficult to apply such criteria because, in most cases, it is impossible to separate hardware from software.

22. Other criteria, such as capital intensity, new or mature technology, industry of origin and end-use (e.g. electrical machinery, consumer durables) are very useful when indicators are designed for individual countries or when industry-specific analysis is carried out.

2. A framework of technology indicators

23. Indicators can be classified using several of the above criteria simultaneously. Because of its more general applicability, the classification which is based on the interpretation of technological change as a process is the main classification used in this report. Therefore technology indicators will be discussed under the following three major headings: (a) input indicators; (b) output indicators; (c) technology-related economic performance indicators.

24. Input indicators can be further distinguished according to the source of the technology.

(a) Imported or transferred technology such as foreign direct investment, imports of capital goods, payments for proprietary technology and technical assistance; and,

(b) Domestic inputs or "efforts", such as resources devoted to science and technology, human resource development and investment in plant and machinery.

25. A distinction between imported technology and domestic efforts is useful on several grounds. Imported technology constitutes a major source of technology for all countries, especially developing countries and as such it deserves to be treated separately. Moreover, by comparing imported technology with domestic efforts, important insights as regards their relative contributions to technological change can be obtained.

26. Regarding indicators of the generation of technology, or "output indicators", it will be shown that the range of indicators, in general, and for developing countries, in particular, is limited due to the overall weak interrelation between science and technology, lack of data and conceptual constraints in defining inventions and innovations across countries.

Technology-related economic performance indicators can be divided into:

(a) Performance indicators related to the domestic economy, such as productivity changes and product innovation.

(b) Export or trade performance indicators, such as changes in market shares of technology intensive products and exports of technology.

27. A separation between domestic performance indicators and export performance indicators is considered, necessary on several grounds. First, it can be argued that domestic performance influences technological competitiveness and thus export performance. Therefore, there is a certain causality between these two types of performance indicators which necessitates a conceptual distinction. Secondly, the degree of countries' export orientation is strongly influenced by non-technology factors such as overall development policies, balance-of-payment conditions, etc., which suggest that domestic and export performance indicators measure different aspects of technological change.

28. Finally, another set of indicators which are often used to measure technological performance includes the level of industrialization and structural changes such as changes in the composition of GDP, the sectoral distribution of labour force and the composition of domestic output and trade. These "structural characteristics" are to a large extent the point in time outcome of technological changes and, hence characterize the level of technological development. Given the scope of this paper, structural characteristics are not considered explicitly.

29. In chapters III, IV and V, input, output and performance indicators are discussed as regards their measurement definitions, theoretical rationale and data availability in order to arrive at an assessment of each indicator's analytical strength. Since indicators are variables that represent an assumed relationship, the major focus is on the interpretation of the indicators.

Chapter III

TECHNOLOGY INPUT INDICATORS

30. Resources devoted to the generation of scientific and technological knowledge form the input side of the science and technology system. For developing countries, it is useful to adopt a broad definition of input elements which includes, in addition to R & D activities, transferred technology and domestic efforts in the form of human resource development and investment in plant and machinery.

A. Transferred technology

1. General

31. The meaning of imported or transferred technology is subject to different interpretations. "Technology transfer" implies that the recipient of technology not only acquires hardware and software but eventually accumulates the technical knowledge, which is necessary to master the imported technology. There is general agreement that countries need to develop specific capabilities in order to achieve this.

32. The international transfer of technology can take place under several forms whose relative importance varies from one country to another. They may involve both commercial and non-commercial flows. The former is mainly realized through the import of "technology-embodying" capital goods (either in the form of individual pieces of machinery and equipment or completely assembled turn-key plants), foreign direct investment, and the transfer of disembodied technology via the licensing of patents, know-how agreements, supply of technical and consultancy services, joint ventures, skilled labour migration, etc. Non-commercially transferred technology, on the other hand, includes, most notably, technical co-operation funded by official government agencies and by non-governmental organizations and customers, and information contained in professional journals and publications.

33. Attempts to quantify internationally transferred technology are faced with serious data constraints, particularly as regards contracts on proprietary technology, new forms of investment, employment of foreign skilled labour and the acquisition of codified information. Moreover, there is a high degree of overlapping among the different sub-categories of transferred technology, since a single transaction often includes more than one form of technology transfer. Foreign direct investment, for example, is frequently combined with licensing agreements between parent companies and affiliates (UNCTC (1987)) and may also involve trade in capital goods. These characteristics need to be considered when individual indicators are interpreted.

34. The selection of individual indicators of internationally transferred technology, which are discussed here, is determined by the availability of data and their statistical relevance for developing countries. They fall in the following categories:

(i) Imports of technology-embodying products;

(ii) Foreign direct investment;

(iii) Payments for proprietary technology; and,

(iv) Technical co-operation grants.

2. Imports of technology-embodying products

35. Imports of technology-embodying products is one of the most important forms of commercially transferred technology. Imports of machinery and equipment as derived from international trade statistics within section 7 of SITC 4/ constitute the most accurate and comprehensive statistical data for measuring such transfers. Several indicators can be constructed by combining or selecting subgroups of SITC 7.

(i) Imports of subgroups of SITC 7 ranked by degree of "technological intensity", (National Science Board (1989), OECD (1989), UNCTAD (1988)) where technology intensity is defined by the R & D intensity of industrial output, e.g. the following subgroups are "high-technology-intensive": aircraft and parts (7114, 734), office machines and computers (7141, 7147, 7143, 7149).

(ii) Imports of capital goods more generally. One possible approach (UNCTAD (1988)) is to exclude from SITC 7 consumer goods, such as domestic appliances (7194), television receivers (7241), radio and broadcast receivers (7250), passenger motor cars and chassis (7321 and 7326), motor cycles and bicycles (7329 and 7331).

36. Another measure of international transfer through technology - embodying products is the imports of specific products from other SITC sections which are considered as having a high-technology content and are used in production, for example, scientific measuring and controlling instruments (861) and optical and medical instruments (5419).

37. The methodology used for assigning products to different technology-intensity groupings has various shortcomings and as will be discussed in the next chapter has been criticized on several grounds.

38. Similarly arguments can be brought forward against using imports of individual products, which are assumed to embody a high degree of technology. This approach is useful when countries with homogeneous productive structure are the subject of the analysis. However, for cross-country comparisons, it is difficult to define such categories of products since technological needs and specialization vary among countries. Due to the difficulties in defining technology-intensity across countries with different industrial profiles, the imports of capital goods, as defined above, would appear to be a more useful measure of transferred technology for cross-country analysis.

39. A major disadvantage of capital goods or other broad definitions of technology-embodying products as an indicator of transferred technology is that little can be said about their technology content. This results from differences, among countries, in the composition of capital goods as well as in the vintage of goods within the same subgroup of imported capital goods. Thus, the share of farm machinery in total capital goods imports is likely to be higher in agro-industry based countries than in developing countries with a strong manufacturing base, and the vintage of e.g. electrical machinery between two developing countries might differ considerably.

40. In conclusion, imports of capital goods are a suitable indicator of the level of transferred technology. Their statistical significance and the availability and quality of data make it an important indicator for internationally transferred technology. The fact that little can be said about its technology content and the efficiency of the actual transfer limits the usefulness of the indicator as an explanatory variable of technological change.

3. Foreign direct investment (FDI)

41. Transnational corporations play an important role in the international transfer of technology. Among the different arrangements through which transnational corporations may transfer technology, FDI is, in value terms, the most important one. It is also the only one for which comprehensive statistical series are available. Other arrangements are (UNCTC (1987)) joint ventures, licensing, franchising, contractual arrangements on management, marketing and technical services, turn-key contracts and international subcontracting.

42. Foreign direct investment involves the financial flows associated with the establishment by a transnational corporation of an affiliate in a foreign country over which the parent firm is assumed to exercise effective control. It may involve either the acquisition of an existing enterprise or the establishment of a new enterprise. FDI is frequently combined with licensing agreements or other forms of contractual arrangements.

43. Data on foreign direct investment is collected by the IMF on the basis of the balance-of-payments statistics provided by countries. Its measurement however involves several problems which are sources of international discrepancies. There problems derive mainly from the following:

(i) level of foreign control of shares defining FDI;

(ii) treatment of reinvested earnings;

(iii) financial sourcing for the development of affiliates; and,

(iv) the sectoral breakdown of FDI.

44. The level of share control (or voting powers) above which an investment is defined as FDI ranges generally from 10 to 25 per cent. Despite the IMF definition and OECD efforts in providing a "benchmark definition", countries differ in their definitions of FDI. Thus, variations in national measurement of FDI may give rise to different values of the same flow of FDI according to whether it is measured by the country of origin or the recipient country.

45. Some countries consider reinvested earnings by affiliates of foreign enterprises as part of the direct investment flow, and they include them in their FDI statistics. Others - particularly developing countries - do not collect data on reinvested earnings. As a consequence, there are some differences between the national evaluations of the same FDI flows and stocks. Usually there is a large excess of net credits reported to the Fund, because debit entries (mainly by developing countries) are less complete than credit entries as compiled by large creditor countries (mainly developed countries).

46. Financial resources for the development of assets controlled by foreign enterprises do not consist only of the registered FDI flows - inwards or outwards flows - as reported in the balance of payments. Other resources are reinvested earnings by affiliates and fund raising on financial markets, either national or international. Therefore, data on reported flows cover only one part of increasing assets. This part becomes smaller with time as the affiliates develop their activities and become able to finance their further growth. One important consequence is that the internationalization of productive operations does not necessarily imply growing international flows of FDI. An indicator measuring stocks rather than flows could be used to tackle this difficulty. Unfortunately, this type of data is not collected in the same way as FDI flows. Accuracy, periodicity, and international comparability are even less guaranteed than in the case of flows.

47. Regarding the technology content of FDI and its relevance as a channel of technology transfer it appears difficult to arrive at generalizations, since a wide range of factors play a role, which vary across countries. The technology that is provided through FDI may include any or all of the following: capital goods; industrial property rights in the form of patents, trade marks and branch names; secret unpatented process know-how that is specific to the investing firm; and the investment of the firm's skills in organization, management and training. On the other hand FDI may not involve any transfer at all, as in the case of simple acquisition of existing firms.

48. To which extent know-how is actually transferred may depend on the transfer costs as viewed from the investor (Teece (1986)) and the economic environment and market characteristics of the host country, which influence the contribution of FDI in the formation of management and technical skills, marketing know-how as well as other spill-over effects by way of direct links with suppliers and customers as well as indirect ones through leaks to other firms of the host country.

4. Payments for proprietary technology

49. Probably the most direct form of technology transfer is through the transfer of disembodied technology. One way of measuring such transfer is by using the payments for proprietary technology e.g. licensing of patents, know-how agreements, management contracts. Information regarding such payments constitutes part of the payments for services in the current account balances under the item Technology Payments (TBP). Although this item, theoretically covers all transactions relating to trade in technical knowledge and services with a technology content, in practice, TBP includes a range of non-technology related flows while excluding some important ones. Furthermore, data is currently available only for OECD countries and, in most instances, it covers only royalties and licensing fees. Improvements in data quality and coverage should, however make TBP a meaningful indicator of international transfer of disembodied technology (OECD (1988), UNIDO (1989)). Hence, the need to include a discussion of the definition, measurement and interpretation of TBP in the present report.

50. Technological balances of payments are generally composed of two categories of payments: those corresponding to commercial transactions on elements protected by industrial and intellectual property rights and those implied by the supply of services with a technical content. Each category

includes largely heterogeneous flows with varying technological content. It is generally considered that technological balance of payments covers a wider range of payments than definitions of know-how would imply.

51. Conversely, there may be technology transfer without associated technological payments. In many instances payments do not appear in the technological balance of payments as they are hidden in other payments such as the profit remittances of transnational corporations. In so far as technology transfers constitute intra-firm flows, reported technological payments tend to depend on the firms' transfer-pricing policies, which tend to be dictated by global strategy considerations rather than by technology costs. 5/ Host countries' legislations on profits and remittances are crucial in transfer-price setting. Since countries' legislations differ significantly in this respect, the correspondance between technology transfers and payments as reported in TBP will vary significantly. This would tend to limit the international comparability of TBP since the same technology transfer in one country may be reported under TBP while in another under profit remittances or vice-versa.

52. Another limitation of TBP, derives from the fact that there is no internationally acceptable definition of which payments constitute trade in technology. The definition offered by the IMF Manual of Balance of Payments is not adequate because it does not make a distinction between the different types of contractual arrangements. Conversely OECD efforts to harmonize the collection and compilation of data are limited to OECD member countries (OECD (1988a)). However, some developing countries have been making efforts to improve their compilation of technological payments for many years. This is the case of countries implementing registration and/or screening systems of contracts implying technological payments (UNIDO (1989)).

53. The technological balance of payments covers a wider field than technological transfers. Besides commercial transactions on licences and know-how, transactions on trademarks, designs and models are also recorded. These different transactions are rather difficult to separate, and in many instances they are part of the same contractual arrangements combining trademark and industrial licences. Furthermore, there are other financial flows which do not correspond to industrial property elements and know-how but to intellectual property rights in general such as copyrights for art products.

54. A second category of technological payments is related to technical assistance taking place between enterprises on a commercial basis. These payments include various kinds of technical services with different technological content: consulting engineering studies, technical assistance, managerial and administrative services, or R & D performed abroad or funded from abroad. Some of these services are associated with technology transfer e.g. in form of licensing agreements.

55. Technology payments, by definition, would be a good indicator for measuring the transfer of know-how or technology not embodied in objects. However, the heterogeneous technology content of technology payments raises a series of questions concerning the interpretation of technology payments particularly when using it together with FDI. Moreover, the use of TBP for international comparisons is severely limited by the poor availability of data for developing countries.

5. Technical co-operation grants

56. Technical co-operation grants are an important form of non-commercially transferred technology. In particular, for less and least developed countries, they represent a major and often the only source of foreign technology. Technical co-operation grants cover the provision of resources by donor countries to developing countries with the primary objective to (a) augment the level of knowledge, skill, technical know-how or productive aptitudes or (b) to augment the capacity for more effective use of the existing endowment (OECD (1988b)).

57. Data on technical co-operation grants from individual donor countries and from multilateral agencies to individual developing countries is provided by OECD. The data concerns total grants only and therefore, it is not possible to identify the elements of technical co-operation grants such as training, fellowships, etc.

58. Overall, it is not possible to quantify at the cross country level the technology content of technical co-operation grants. The size of co-operation grants is influenced not only by technological requirements but also by political constraints and priorities. Moreover, investments in human capital formation involve long time-lags and this makes it difficult to assess the role of technical co-operation grants. Despite these limitations, it is indispensible to take this indicator into account, since for many developing countries technical co-operation constitutes a major inflow of technology. Its evolution over time and its distribution across countries are important features of developing countries' economic and technological strengths.

B. Domestic technological efforts

1. General

59. Domestic technological efforts in the form of R & D activities, human resource development, and physical investment are fundamental input elements for accelerating technological change. Their importance is two-fold. First, they are a necessary pre-condition for building up indigenous technological capabilities. Secondly, sustained domestic efforts are crucial for the effective utilization of imported technology.

60. The role of domestic technological efforts in influencing the level of technological mastery of imported technology is of particular importance and raises a series of interesting questions. Thus, a central question in interpreting and assessing imported technology and domestic efforts, at the macro level, relates to the balance between them and the dynamic interaction of their different elements.

61. The nature of domestic technological efforts and their impact on technological accumulation are influenced by a wide range of factors which include the physical and institutional infrastructure, financing systems, market characteristics and policies. Moreover, these factors influence the interactions between R & D activities, human resource development and physical investment. Data and conceptual constraints make it impossible to take these aspects into account in the construction of indicators. It is, therefore, necessary to discuss measures of R & D activities, human resource development

and physical investment separately. However, one has to be aware that they are strongly interdependent and that they are influenced by the techno-economic environment.

62. Finally, it is important to distinguish conceptually between domestic technological efforts as input elements into the process of technological change and as domestic technological capabilities. While the first is a dynamic concept, the second is the point in time outcome of technological change, reflecting progress achieved in the past.

2. Research and development (R & D) activities

63. R & D has become a widely accepted indicator of innovative activity. R & D indicators have attracted the attention of policy makers, since scientific knowledge is increasingly needed for the development and application of advanced technologies. National institutions and international organizations such as UNESCO and OECD have undertaken considerable efforts to make R & D statistics comprehensive and comparable.

64. According to UNESCO, research and experimental development is broadly defined as "any systematic and creative work undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new application". The resources devoted to research and experimental development are defined as the "core" of scientific and technological activities. Other science and technology indicators used by UNESCO are: "scientific and technological education and training broadly at the third level" and "scientific and technological services (STS) performed or financed by all national institutions in the fields of natural science, engineering and technology, medical and agricultural sciences as well as in the fields of social sciences and humanities".

65. Two broad categories of R & D indicators can be distinguished: R & D expenditures, which capture the financial resources, and human resources employed in R & D activities. The global figures give only a measure of the intensity of R & D activity. Additional information about the internal structure of R & D is, however, necessary when analysing the technological effort itself and for international comparisons. Gross Domestic Expenditure on Research and Development (GERD), as provided in national accounts, is the indicator used for R & D expenditures. The indicators describing the internal structure of R & D are obtained by disaggregating GERD using mainly the following criteria:

(i) Type of R & D activity - basic research, applied research, experimental development;

(ii) Sector of performance - productive sector, higher education, general services;

(iii) Branch of economic activity in the productive sector; and,

(iv) Source of funding: Public, private.

66. As regards human resources, the total number of scientists, engineers and technicians engaged in R & D, expressed in full time equivalent, is

disaggregated by field of study, sector of performance or branch of economic activity. For the purpose of international comparisons various standardized ratios are constructed, including:

(i) R & D expenditures as a share of economic resources (GNP);

(ii) R & D expenditures per capita;

(iii) R & D personnel as a share of total scientists or engineers; and,

(iv) R & D personnel per 10,000 employees in the corresponding sector.

67. Despite efforts by UNESCO in providing guidelines for definition and measurement techniques, developing country data on R & D activities are of only limited international comparability (see Teitel (1987)). The definition of scientists and engineers, for example, is not uniform across countries, the years for which data is available are not the same in each case and in some countries data on R & D expenditures is available only for the public sector. Besides data constraints which make time series analysis impossible, there are both general problems in interpreting R & D activities as well as problems specific to developing countries.

68. In general, R & D indicators measure only formal R & D and neglect two important sources of scientific input: production engineering departments in large firms and part-time innovative activities in small firms. As a result, R & D indicators tend to underestimate the volume of scientific input directed towards production technology and related capital goods (Patel and Pavitt (1988)). However, on the whole, measures of R & D activity can be used as indicators of domestic technology efforts but in developing countries need to be interpreted with caution because of the lack of uniformity in the quality of the data collected by UNESCO.

3. Human resource development

69. There is general agreement that human capital formation in the form of education and training is an essential ingredient for development. In this respect educational systems are of particular relevance since they shape to a large extent the levels of skills embodied in the workforce.

70. UNESCO provides definitions on educational systems and technical manpower and collects data on literacy, educational enrolment at the first, secondary and tertiary level as well as data on vocational training. Concerning data on, what UNESCO defines as, the "scientific and technical manpower potential", the information available is of a very general nature. The data covers the total numerical strength of the most qualified human resources, defined by either the total number of, or the number of economically active, persons who possess the necessary qualifications as scientists, engineers or technicians.

71. Based on the available information as provided by UNESCO, the following indicators are frequently used to assess the skill-potential of countries (see e.g. Lall (1990)):

(i) Adult literacy rates;

(ii) Enrolment in primary, secondary and tertiary education as a percentage of age groups;

(iii) Tertiary level students by technical fields (general science, natural sciences, engineering) as percentage of population;

(iv) Enrolment in vocational training as percentage of population or of employees in the manufacturing sector; and,

(v) Number of scientists, engineers and technicians per million population.

72. Once again, the coverage and quality of the data leave much to be desired. Definitions, for example, are not uniform across countries, the years for which data are available are not the same for all countries and for many countries the data are simply out of date. These data constraints are particularly severe for data on higher education, vocational training and number of scientists. Moreover, important firm-specific forms of training, such as on-the-job training, are not included. Another, and probably more important limitation results from the conventional classifications of levels of education. They fail to take into account that the degree and specialization of skills need to correspond with the actual industrial requirements, which in turn are determined by the types of applied or planned technologies.

73. Despite these general shortcomings, indicators of human resources are indispensible for assessing countries' technological input. There is general agreement about the link between levels of education and economic development (Dean (1984)). It is also beyond doubt that basic education is important for all production techniques, irrespective of their degree of sophistication. Accordingly, literacy rates do provide an indication of the overall quality of the workforce. Similarly, proportional shares of secondary and tertiary educational levels give valuable indication of the existing levels of higher skills and ratios of scientists and engineers of approximate levels and pools of more specialized skills.

4. Domestic investment in plant and machinery

74. The rate of investment determines the pace at which new processes, incorporating new technologies and/or leading to the manufacture of new products are incorporated into the country's capital stock and diffused through the economy. In this sense, domestic investment in plant and equipment can be considered as crucial to the realization of technological opportunities. However, an increase of physical capital and a corresponding output growth, alone, is not sufficient to accelerate technological change. In a dynamic setting, an increase in capacity needs to be accompanied by technological learning, increased process innovativeness and product improvements. Hence, domestic investment needs to be seen as a necessary but not sufficient condition for technological change.

75. Data on Gross Domestic Investment (GDI) for developing countries are collected by UNSO, the World Bank and regional commissions of the United Nations system. GDI is derived from national expenditure accounts and includes: all new equipment produced domestically or purchased from abroad as well as all imported second-hand goods; all new dwellings; expenditures on the

improvement of durable goods and non-reproducible tangible assets (such as land, mineral deposits, plantations); and additions to livestock herds. Commonly used indicators based on GDI are:

(i) Flows of GDI, its changes over time and its share in GNP as a measure of overall investment activity;

(ii) GDI per capita or per employee in the manufacturing sector as measures of investment intensity or capital intensity.

76. Capital goods constitute a very important vehicle of technologies used in the production process. In the same way as imports of capital goods are one form of acquisition of technology, production of capital goods represents a means of developing domestic technological capabilities. At the international level, data on production of capital goods is obtained from UNIDO's industrial production statistics tabulated according to the International Standard Industrial Classification (ISIC). Based on this data it is possible to construct estimates of domestic production of capital goods as a component of domestic investment. ISIC 381 to 385 is a widely used classification of capital goods (UNIDO (1985), UNIDO (1979)). This category includes metal products (381), non-electrical machinery (382), electrical machinery (383), transport equipment (384) and professional and scientific equipment (385). Major disadvantages with this data is the limited country coverage (about 35 major developing countries) and insufficient adjustments for exchange rate fluctuations and inflation.

77. On the basis of the same statistics, several flow and stock indicators and ratios can be constructed:

(i) Flows of domestic capital goods output or its share over total manufacturing output to measure the domestic investment in hardware embodying technology;

(ii) Depreciated stocks of domestic capital goods to estimate the installed productive capacity;

(iii) Stocks of domestic capital goods per employee in the manufacturing sector to approximate degrees of mechanization.

78. Domestic capital goods (production less exports) in combination with imported capital goods are by far a better indicator for changes in the productive capacity than GDI. The latter provides only an aggregate picture of investment activities. Furthermore, it contains an unknown though not unimportant component which does not correspond with investment in plant and equipment. By contrast, investment in capital goods measures the physical scope for productive activities. Changes in capital stocks indicate rates at which machinery is renewed and - implicitly - a country's potential to benefit from newer technology. Similarly, the level of domestic capital goods production reflects technological capabilities of countries. Leaving aside cyclical or demand related influences on the output of domestic capital goods, their volume and composition reflects technological capabilities accumulated in the past.

Chapter IV

TECHNOLOGY OUTPUT INDICATORS

79. There are as yet no direct measures of the "output" of technology. The only indicators used are based on data collected for other purposes. The most commonly used output indicators in OECD countries are based on patent activities and scientific publications. The use of these indicators for developing countries raises a series of complex questions, which result mainly from the different links between science and technology in these countries.

80. The use of patents as an output indicator of scientific and technological activities has been developed since the pioneering work of Scherer and Schmookler (1965). Improvements of data banks on patenting activities, in general, and of the United States Patent Office, in particular, have led to numerous studies on patent activities. 6/ Most of these studies have focused on OECD countries. For developing countries there is hardly any empirical evidence on the role of patents. The second output indicator, bibliometrics, constitutes a relatively controversial area of science and technology indicators. Initially it was science historians and scholars who found interest in bibliometrics since the early 1960s as a research tool in the history of science.

A. Patent activities

81. A patent can be defined as a statutory privilege granted by a Government to inventors for a fixed period of years, to exclude other persons from manufacturing, using or selling a patented product or process. The major function of patents is to encourage innovation by granting monopoly rights to industrial property right holders and to promote the general welfare by striking a balance between encouragement of creation, on the one hand, and diffusion of the creativity, on the other.

82. Patent data are collected by WIPO, whose membership numbers over 170 countries and territories. Patent data are classified according to IPC (International Patent Classification) which differs from both ISIC and SITC. The IPC classification is product based. It includes five sections: human necessities; performing operations and transport; chemistry and metallurgy; textiles and papers; and fixed construction and mechanical engineering. Four categories of patent indicators are frequently used:

(i) Applications filed (patents granted) in a country by (to) its nationals and residents;

(ii) Applications filed (patents granted) in a country by (to) non-residents;

(iii) Total applications or granted patents ((1) + (2));

(iv) Applications filed (patents granted) abroad by (to) residents of a country ("external patenting").

83. The use of domestic patent activities (i) to compare innovative activities across countries involves several problems. First, examination procedures and the ratio of granted patents to applications vary considerably

across countries. Secondly, the overall role of intellectual property systems depends on the technological development level and industrial development strategies. Thus, several developing countries have not yet, or have only recently, introduced effective patent laws. Thirdly, in developing countries, non-residents and multinational corporations account for the lion's share in filed patents. 7/ Accordingly, domestic patenting activities in developing countries are strongly influenced by multinational corporations, and this limits the usefulness of domestic patenting as an indicator of indigenous, innovative activities. Fourth, country differences in patent systems may also result from differences in industry specialization. The propensity to patent is strongly influenced by industry-specific characteristics, which determine the patentability of products or processes, i.e. the ease with which they can be imitated. Thus, patents have traditionally played an important role in chemistry and pharmaceuticals whereas in electronic consumer products or machine-building they are of relatively little relevance. Overall, the international comparability of domestic patenting activities is limited, particularly so for developing countries.

84. In order to neutralize country differences in patent systems, it is necessary to rely on external patenting. Here, indicators on patenting activities are mainly used to explain international differences in innovativeness with respect to trade. The superiority of external over domestic patenting as a technology output indicator has been empirically verified for OECD countries. 8/ Comparative analysis of external patenting in individual selected OECD markets has shown that external patenting in the United States is the best direct measure of international innovative performance (Soete (87)). The relatively better performance of the United States market as opposed to other OECD markets can be explained by its large size and importance as an export market. Various ratios and derived indicators have been constructed for more refined empirical analysis:

(i) To remove the country-size factor when technology input indicators and external patenting are compared, both are weighed by population;

(ii) To take into account the commodity composition of trade flows, Revealed Technology Advantage Indexes (RTA) are constructed. The RTA is exactly equivalent to the index of revealed comparative advantage used in trade analysis and compares a particular country's share of United States patenting within a sector, divided by that country's share in total United States patents. An RTA of over one shows a relative technological advantage;

(iii) In industrial analysis a country's exports in an industry is compared with the number of external patents; in this case both variables are normalized by population.

85. Although external patenting statistics appear to be a good output indicator in explaining differences in innovative activities among OECD countries, there are some drawbacks even for these countries which can be summarized as follows (Pavitt (85), Soete and Wyatt (82)):

(i) The propensity to patent in a certain export market is also influenced by the relative importance of that market;

(ii) International differences in patent classification systems hinder comparisons, particularly at the industry level;

(iii) Patenting activities vary considerably across industries and therefore generalized conclusions must be treated with caution. Thus, patents do not equally reflect innovativeness across industries but are largely a function of inter-sectoral differences in the relative efficiency of other barriers to imitation available to the innovator (e.g. secrecy, technical lags).

86. Although external patenting has proven to be a powerful indicator of innovative activities across OECD countries, its usefulness to explain developing countries' innovativeness is less obvious as the absolute number and share of developing countries' residents in external patenting is still very small. 9/ This makes it impossible to relate patent activities to industries or products. Even when only aggregate patent data (e.g. patents granted in the United States) by developing countries' residents are used, the numbers are too small to allow comparative analyses. Only for the most advanced developing countries are patent data of statistical importance.

87. In conclusion, patent activities of developing countries are only of limited usefulness in measuring technology output. Country-specific differences in examination procedures and industrial specialization as well as different emphasis of developing countries in using patent systems as a policy instrument to promote technological innovation render comparisons of domestic patenting activity difficult. Regarding external patenting, the small number, in absolute terms, of developing countries' applications for, or granted, patents in export markets hinder international comparisons.

B. Bibliometrics

88. Scientific publications (articles and books) and references are considered as a measure of the results of scientific and technological activities. Bibliometrics is the generic term used to describe data about publications. Compilation of scientific publications is not organized in every country on a systematic base and there is no international institution engaged in collecting and analysing data. A frequently used data-base is the Science Citation Index (SCI) created by the Institute for Scientific Information (ISI) of the United States (National Science Board (1989)).

89. The ISI selects, compiles and publishes bibliographies in every scientific field. It also maintains a data-base on scientific and technological publications and provides information services on scientific activities. The Science Citation Index includes publications in nine scientific fields (from clinical medicine to mathematics through physics and engineering technology). Within the main categories, publications are also classified in 106 specialities and according to the country of origin.

90. The original source used by ISI to build the SCI consists of a large group of influential journals (3,500 for the 1981 SCI corporate tapes of ISI). The original sources and the compilation procedures used raise different issues as regards both the international comparability of data within the data-base as well as its accuracy for measuring scientific

production outside the United States. Several factors suggest the need for caution in using bibliometric data as indicators of the result of science and technology activities in developing countries. First, the scientific journals used in the bibliographical indices, which serve as a basis for the construction of these indicators, do not include an adequate proportion of journals from developing countries (Teitel (1987)). Secondly, language is a barrier which tends to cause underestimation of the contribution of scientists in developing countries (Velho (1985)). Thirdly, and probably most importantly, science and engineering activities in developing countries are more concentrated in such activities as modification and incremental improvement which, while valuable in many respects, are not necessarily of publishable value. Finally, publishing facilities and access to the latest journals are more restricted in developing countries.

Chapter V

TECHNOLOGY-RELATED INDICATORS OF ECONOMIC PERFORMANCE

A. General

91. Although it is generally acknowledged that technological change is a fundamental determinant of economic growth 10/ and international competitiveness, 11/ it has proven notoriously difficult to design meaningful indicators which reflect the role of technology in economic performance. This has to do with the complex nature of technology and the dynamic interplay of numerous other factors which are difficult to isolate. Thus, the obvious relationship between technology inputs and domestic performance on the one side and domestic performance and competitiveness on the other side are difficult to grasp, for they are interdependent and the involved time lags are variable across industries and countries.

92. It is therefore not surprising that there is no single indicator that would adequately reflect technology-related economic performance. Instead, there are numerous indirect measures which fall into two broad categories:

(i) Indicators which are used to relate technological progress to domestic economic performance and

(ii) Indicators which attempt to capture the role of technology in trade performance.

93. Before discussing individual indicators, it is necessary to point out that their application and interpretation is often subject to underlying theories of trade and development. Given the scope of this paper, it is not possible to adequately cover these issues. Instead, only some important aspects are discussed, which help to interpret the technology dimension of the variables.

B. Productivity and technological change

1. General

94. The link between technological change and productivity can be best interpreted at the firm level. Here, productivity improvements can be associated with process innovation and product innovation. Process improvements, achieved e.g. by the introduction of new equipment, organizational changes and incremental learning, lead to productivity gains through improved cost efficiency and improvements of quality. The impact of product innovation on productivity is less clear. The introduction of new products or the improvement of existing products are reflected in productivity changes only to the extent that the cost-benefit relation between inputs and outputs improves accordingly. These firm level considerations are also valid at the aggregate national level although the interrelation is less clear due to variable time lags across firms and industries.

95. Many articles elucidate the methods of computation, their pitfalls, and difficulty of interpretation, particularly within the context of developing countries. 12/ One problem in measuring productivity in developing countries

is the relatively short time period for which the requisite data are available. Short time series may be unduly influenced by changing capacity utilization levels and cyclical variations. Changing levels of capacity utilization are particularly vexing, since it is often not clear whether they result from supply-side bottlenecks such as shortages of material or intermediates, from demand fluctuations or whether they reflect incremental learning. 13/

96. Among the productivity measures which are in wide use, one may distinguish between total factor productivity (TFP), which seeks to identify the sources of output growth and partial productivity ratios, where output changes are related to a single input, such as labour.

2. Total factor productivity (TFP)

97. TFP is technically defined as the ratio of the rate of growth of output and the weighted average of the rate of growth of inputs in terms of labour and capital. Thus, TFP changes are computed by subtracting from output changes the input changes, weighted by their cost shares. The share of the growth of output which cannot be explained by growth in labour and capital inputs is generally interpreted as "technical progress".

98. In TFP analysis, the focus may be either on the share of TFP growth over output growth or on in rate of growth of TFP. Although both approaches may be useful, there are cogent reasons for using the absolute rate of growth of TFP for inter-country comparisons. 14/ Even in the case of absolute rates of growth interpretation of inter-country or inter-industry differences is complicated by the effect of different initial levels of technological development and economic structures of the countries or industries concerned.

99. A further constraint in measuring and using TFP is the availability of reliable data. Industrial statistics on the sub-sectoral level are available for a limited number of countries only. Moreover, these data are often based on national currencies, and distorted by e.g. rapid inflation or protected markets. In order to arrive at internationally comparable data, considerable adjustments are necessary and a number of additional assumptions regarding currency conversions need to be introduced.

3. Partial productivity measures

100. The most familiar concept of productivity is that of partial productivity - for example, the average productivity of a single input, such as labour. This is generally measured by the value of output per unit of input. Depending on the level of aggregation, a variety of measures for labour and capital productivity are commonly used:

(i) Changes of GDP per capita;

(ii) Changes of manufacturing output or value-added per capita or per employee;

(iii) Investment as percentage of GDP divided by the growth rate of output, commonly referred to as Incremental Capital Output Ratio (ICOR) or "investment productivity" if its inverse is used;

(iv) Various refined capital productivity ratios where capital or output are disaggregated into e.g. imported and domestic components or output in specific sectors such as manufacturing.

101. In addition to the aforementioned problems of interpretation, which constrain all productivity measures, partial productivity measures suffer from the fact that they do not permit us to draw conclusions as to the relative contribution to productivity increase of the two factor inputs. Thus, an improvement in capital-output ratio may be due to improved labour productivity arising from changes in industrial organization rather than to superior investment efficiency of new capital. Similarly, labour productivity improvement may result from process innovations rather than from improvements in labour itself. A basic underlying problem is the substitutability between capital and labour which varies greatly among developing countries. Some of the issues involved are discussed in the following section on "factor intensity of trade".

102. Among the partial productivity ratios, it is value-added per employee, which appears to be the most suitable for approximating technological performance. As Hirsch (1974) has convincingly demonstrated, value-added per employee does not necessarily stand for capital intensity. Higher value-added of one country could be attributed to a more highly skilled labour force whose employment costs would be higher than those of a relatively unskilled labour force. Accordingly, value-added may relate to the contribution of both physical capital and human skills and is therefore a suitable aggregate indicator to approximate the effects of technological change.

C. Trade-related measures

1. General

103. Various trade-related measures also give indications of the competitive strength of countries and industries and can thus serve as indirect measures of technological performance. Exposure to international competition appears to be particularly suitable to identification of the technological strength of countries and industries as it makes it possible to relate a country's performance to average global performance and, implicitly, to the global dynamics of technological change. Technological change influences international competitiveness in at least two ways. First, the creation and introduction of new products is increasingly associated with a high technology content and it is these knowledge-based, high value-added and income-elastic products which capture a growing share of global trade. Secondly, the diffusion of innovations across industries also changes competitiveness in more traditional industries by altering costs of production. Accordingly, measures of trade performance which attempt to capture the role of technology reflect a country's ability to generate or adopt innovations and reveal its pace of technological advance relative to other countries. Commonly used technology-related trade preformance measures are:

(i) General measures of trade performance such as market shares or revealed comparative advantage;

(ii) The behaviour of trade in technology-intensive areas, based on:

factor intensity,
R & D intensity,
external patenting,
selected products such as capital goods;

(iii) Exports of technology:

embodied in foreign investment outflows,
receipts of technology payments.

2. General measures of trade performance

104. As in the construction of other types of measures of technology-related economic performance, absolute values must be transformed or normalized in order to arrive at analytically meaningful measures of trade performance. The different measures used for trade performance fall into three broad groups:

(i) Export performance measures, such as:

Growth of exports per capita or per employee,

Changes of market shares (a country's exports over world exports),

Changes of revealed comparative advantage (share of a good in a country's export relative to the good's share in world exports: RCA),

Constant market share analysis (CMS);

(ii) Trade balance measures, such as:

Changes of trade balances of goods (exports - imports),

Changes of normalized trade balances (exports minus imports over exports plus imports);

(iii) Trade orientation of production measures such as:

Export orientation (exports as a share of production),
Import penetration (imports as a share of consumption),
Self-sufficiency (production as a share of consumption).

105. The question of choice of performance indicators depends on the purpose of the analysis. Generally, export based measures are preferred because they permit stronger inferences about a country's technological competitiveness than do trade balance or trade orientation measures. The inclusion of imports and production in the latter two types of measure introduces more strongly the effect of domestic economy policies and demand variations which tend to distort imports more than exports (Balassa (1977)).

106. Among the export performance measures, technical and data as well as analytical strength for deriving policy implications differ considerably.

Normalized growth rates (per capita, per employee) and market shares make it possible to neutralize the effect of global growth of trade in the corresponding product category or industry. The RCA builds on this approach and includes the commodity composition. Depending on the level of disaggregation, relative strengths and weaknesses of individual countries' export composition can be thus identified. The CMS technique goes one step further. The decomposition of export growth into commodity, market-distribution and competitiveness effects, makes it possible to analyse and isolate the relative importance of geographical concentration on export performance. The need for exercising caution in interpretation of RCA and CMS, on both theoretical and empirical grounds, is extensively argued in the literature. The usefulness of the RCA and CMS for interpreting the influence of technology aspects is limited unless further assumptions are made. For example, linking RCA with product cycle theory allows identification and analysis of sequences of industries in which relative efficiency is likely to grow. Similarly, regression analysis based on assumptions derived from trade theories can be used to reduce further the unexplained competitiveness residual of the CMS.

107. However, reliance on export-based measures alone has its disadvantages. First, re-exports are not isolated although the use of value-added would help to circumvent this shortcoming. Secondly, intra-firm trade, which is difficult to correct for and which may have little to do with the host country's competitiveness, distorts the picture. Thirdly, the focus on exports masks a country's ability to fulfil its own market requirements. This aspect is of relevance if countries induce export expansion by policy measures that discriminate against the domestic market.

3. Technology intensity of trade

108. Various approaches attempt to define and structure the commodity composition of trade according to criteria of technological intensity. By comparing countries' performances with a technology-intensity scale of trade, conclusions can be drawn on their relative abilities to upgrade comparative advantage towards more knowledge- and skill-intensive industries. Each approach has its specific area of application and conclusions on countries' technological performance are tied with numerous underlying assumptions. Among the commonly used approaches those built on factor-intensity and of R & D intensity of trade are briefly reviewed below.

(a) Factor intensity of trade

109. One of the "stylized facts" of industrial development is that, with rising income and an increase in the stock of human capital, the pattern of specialization shifts towards higher value-added and capital-intensive industries. Accordingly, a country's relative technological performance is often analysed by examining the changing factor intensity of its trade. Various approaches have been used. 15/

110. Most typically trade statistics are grouped according to the following measures of capital and labour intensity:

(i) Gross fixed investment per employee;

(ii) Stock of capital goods per employee;

(iii) Value-added less wages over number of employees;

(iv) Wages per employee.

111. Relating trade performance to indicators of capital and labour intensity permits conclusions to be drawn as to the nature of countries' comparative advantage, and is a useful complement to more strictly technology indicators.

(b) R & D intensity of trade

112. The classification of industry and product groups according to the importance of R & D expenditures is one of the most common approaches used to define the technological intensity of output and trade. A country's ability to excel in high R & D-intensive industries or product categories can be viewed as an indication of its competitiveness in industries with high growth potential.

113. R & D intensity is measured by the ratio of R & D expenditure to production. This ratio is calculated for each industry at a given level of disaggregation. 16/ The different industries are then ranked from high to low and their R & D intensity is compared to the average R & D intensity of industrial output. 17/ Industries with R & D intensity above this average are defined as "technology intensive". Alternatively, several levels of "technology intensity" can be defined by grouping together industries with similar levels of R & D intensity, as shown in table 1 where the ratio of R & D expenditure to production for several industries is shown for 18/ OECD countries. The R & D intensity of trade products or product groups is the same as the R & D intensity of the corresponding industrial output.

114. The concept of R & D intensity has been widely used. 19/ Its major drawbacks are that the definition of the R & D classifications is highly sensitive to the year that is used as a benchmark and country coverage. 20/ (Soete (1987)). They also ignore the intra-industry diffusion of innovations (Palda (1986) and Hughes (1988)). The latter point is of particular importance to developing countries since, for technological followers, diffusion of innovations is often more important than the generation of innovations. The diffusion of innovation across industries is, however, not necessarily related to the R & D efforts of the industry where the innovation is generated.

115. A further complication arises from the dispersion of production processes across national boundaries. The low-skilled, labour-intensive part of producing a more or less complex final good is often shifted from the advanced industrialized countries to low-wage countries. Typically, this relocation is carried out by multinational corporations. Since the production of the intermediate parts usually falls in the same industry category as the final good, low-wage countries may appear to have a relatively large share of high-tech products in their total exports. In general, this reflects not these countries' capacity to produce high-tech products sui generis but rather the fact that they have a comparative advantage as a locus of production.

Table 1

Ranking of R & D intensities for 1980

		R a/
High		
1. Aerospace		22.7
2. Office machines, computers		17.5
3. Electronics & components		10.4
4. Drugs		8.7
5. Instruments		4.8
6. Electrical machinery		4.4
	Average	11.4
Medium		
7. Automobiles		2.7
8. Chemicals		2.3
9. Other manufacturing industries		1.8
10. Non-electrical machinery		1.6
11. Rubber, plastics		1.2
12. Non-ferrous metals		1.0
	Average	1.7
Low		
13. Stone, clay, glass		0.9
14. Food, beverages, tobacco		0.8
15. Shipbuilding		0.6
16. Petrol refineries		0.6
17. Ferrous metals		0.6
18. Fabricated metal products		0.4
19. Paper, printing		0.3
20. Wood, cork, furniture		0.3
21. Textiles, footwear, leather		0.2
	Average	0.5

Source: OECD (1986)

a/ R: Ratio of R & D expenditure to production.

(c) Trade performance in selected product groups

116. Another way of measuring technology intensity in trade is by focusing on specific products which are generally viewed as "new technology", "advanced technology", "core technology" or "strategic technology". Such terms are usually associated with products or activities to which a combination of characteristics can be attributed such as: the need for a strong

R & D effort; high growth potential; rapid product and process obsolescence; high-risk and large capital investment; high degree of international co-operation; competition in R & D and marketing; and high skill-intensity.

117. On the basis of the assumption that the current global industrial transformation is driven mainly by electronics-based innovations, it would appear justifiable to define e.g. the share or growth of trade in electronics products as an indicator of technological performance. The question of which electronics products to choose raises several questions and it appears difficult to establish a global definition. Differences across countries regarding industrialization strategies, areas of specialization and intra-industry differences as regards the generation and diffusion of electronics products suggest that internationally comparable standards are difficult to design. Such approaches appear to be more powerful in industry-level analysis, where specialized data is available that makes it possible to take into account diffusion patterns and degree of application.

118. A third approach to defining technology-intensive products is through definitions of capital goods (see discussion on imported technology) or engineering products. Since such products are a form of embodied technology, it appears justifiable to associate technological performance in exports with a country's ability to successfully export capital goods. By applying general trade performance measures, countries' technological performance can be analysed by e.g.:

Rate of growth of capital goods in exports.
Trade balances in capital goods.
Share of capital goods in total manufactured exports.

119. Since capital or engineering goods are of strategic importance to all countries' productive capacities, the interpretation of these indicators has fewer drawbacks than the narrower definitions of technology intensity, for example the indicators based on specific high-technology products. Nevertheless, their interpretation is not free of biases. Structural differences among developing countries and different export specializations suggest the need for caution in interpreting export performance in capital goods.

4. Export of technology services

120. Data on exports of technology services are valuable indicators of the technological strength of countries. Such services typically include technical know-how, technical and management services, and "embodied skills", such as technological dissemination associated with project exports.

121. In practice, such services are a component of investment abroad and overseas construction, licensing and technical agreements and an array of other commercial tie-ups such as joint ventures in e.g. research or marketing. As has been discussed in the section on technology imports, there are serious conceptual problems in identifying the technology content of foreign direct investment and secondary data on other forms of disembodied technology flows are not available.

Chapter VI

SUMMARY AND CONCLUSION

122. Despite the importance attached to the role of technology in trade and development, work on empirically validated technology indicators relevant to developing countries has been seriously neglected. This report seeks to fill this gap. On the basis of internationally published and comparable data an extensive review has been carried out, identifying and assessing the usefulness and applicability of science and technology indicators for developing countries. The review shows that there exists a wide range of indicators that can be used in making international comparisons. Each indicator has its own strengths and weaknesses, and any international comparison should use a range of indicators adapted to its purpose.

123. For the purpose of classifying technology indicators it is useful to adopt a broad definition of technology and to distinguish between technology input, technology output and technology-related performance indicators. For all countries, but particularly for developing countries, it is useful to divide further measures of technology inputs into imported technology and domestic technological efforts. Indicators of imported technology are constructed from statistics on capital goods imports, foreign direct investment, technical co-operation grants and on the more direct acquisition of technology in the form of licences and know-how agreements. Domestic technological efforts fall into three broad categories of human capital formation, R & D activities and investment in equipment. Indicators of technology generation or output are based on patent statistics (domestic and external registrations) and bibliometrics. Indicators of the economic impact of technological change refer either to the domestic economy or to foreign trade. Various measures of productivity are used to estimate the domestic economic impact of technological change. The influence of technological factors is also reflected in the structure and composition of a country's output and exports. Technology-related trade performance can to a certain extent be examined through techniques of revealed comparative advantage and analysis of market shares, through commodity classifications according to R & D intensities and external patent activities, and through an analysis of technology exports, chiefly in the form of capital goods and receipts for technology payments.

124. The usefulness of the indicators discussed in this report depends largely on the availability and quality of data, although problems of interpretation also need to be taken into account. In general, it is the input side which can be best quantified and assessed. Thus, for example, the role of transferred technology and its composition relative to domestic technological efforts can be analysed with relative ease, whereas less can be inferred from the available statistical data about the process of technological change itself. We may only assume that scientific and technological inputs drive the pace and direction of technological change. What can be measured and interpreted, however, is the outcome of the process of technological change, in which these inputs have been used.

125. The discussion on the indicators on imported or transferred technology showed that the availability of internationally applicable data as well as the technology content of the indicators varies considerably. For international

comparisons it is, therefore, necessary to apply the widest possible range of indicators. The statistically most reliable and most important indicators, in value terms, can be derived from trade statistics. Thus, indicators on capital goods imports provide a good picture on the quantitative aspects of the acquisition of embodied technology. Statistics on foreign direct investment and technical co-operation grants provide indispensable indications on transferred technology. However, it is difficult to measure their technology content and their interpretation requires taking into consideration country and industry-specific characteristics. Lack of data and measurement difficulties limit severely the usefulness of measures of direct transfers of technology.

126. Turning to domestic technological efforts, output of capital goods would appear a suitable indicator for measuring the domestic component of investment in equipment. Data constraints are particularly severe regarding the measurement of human capital formation and R & D activities.

127. The technology output indicators considered, i.e. patent activities and bibliometrics, were found to be of limited usefulness in measuring the outcome of scientific and technological efforts in developing countries. The major reason for this is that such indicators are designed to measure advances relative to the world scientific and technological frontier. Even when external patenting is used, the small number of external patents granted to developing countries does not allow international comparisons. Therefore, these indicators are of relevance for only a small number of relatively advanced developing countries.

128. Among the technology-related economic performance indicators of relevance to the domestic economy, productivity measures would appear to be the most suitable for analysing the outcome of technological change. The close link between process improvements, which is a central feature of technological upgrading, and productivity changes makes the latter a suitable indicator for measuring the pace and direction of technological change. The choice of productivity indicators is largely determined by the availability of data. Due to the scarcity of industrial statistics it is difficult to take advantage of the analytical superiority of TFP over partial productivity measures. Among the partial productivity measures, value-added per employee would appear the most useful aggregate because it includes the effects of both human and physical capital.

129. There is a wide range of indicators which can be used for the assessment of the technology-related performance of exports. However, the specific features of each indicator must be taken into account when examining and interpreting the empirical evidence. Thus, for example, concepts based on R & D intensity or patent intensity do not provide an overall account of technological performance in exports. They fail to take into account technological upgrading in non-science based industries or product innovation in industries where patent protection plays a minor role.

130. Similarly, factor intensities of trade need to consider the underlying assumptions concerning the substitutability of capital and labour. Ratios and shares in capital goods exports have the fewest limitations and, in view of their important role for technological development, they would appear as suitable general indicators of technology-related performance in exports.

131. Overall, internationally available data makes it possible to construct a wide range of indicators which permit analysis of certain aspects of the role of technology in trade and development. In areas where the existing indicators appear to be weak particularly as regards developing countries, efforts for improving quality, consistency and coverage of data by the agencies collecting the relevant data could be reinforced. Efforts should also go into the construction of indicators measuring aspects of technological change which are specific to developing countries as was seen in the various parts of the present report.

Notes

1/ For relevant statistical yearbooks see annex II.

2/ For firm studies see e.g. Katz (1987) for Latin America; Fransman (1984), Dahlman (1987) and Enos and Park (1987) for Asian countries; and Lall (1990), for semi- or nearly industrialized countries.

3/ For recent contributions see Freeman (1982), Rosenberg (1987), Dosi et al. (1988).

4/ Standard International Trade Statistics. Which are considered as having high technology content. Data is provided by UNSO, GATT, OECD.

5/ It has been argued that the higher the FDI flows the more difficult it becomes to interpret TBP, since in this case, the share of intra-firm flows in total TBP tends also to be higher. Madeuf (1984).

6/ See e.g. Patel and Pavitt (1988), Pavitt (1982, 1985), Saviotti and Metcalve (1984), Soete and Wyatt (1983), Soete (1987), Basberg (1987).

7/ Local residents account for only 25 per cent of filed patents in developing countries between 1973 and 1987 (WIPO statistics).

8/ External patenting of a country should include all the patents granted to its nationals and residents abroad. Since, however, a patent application may be filed in more than one country aggregating over countries would involve considerable double counting. It is therefore, customary to look at the foreign patents by the country of origin of the applicant or patent holder in single markets.

9/ The share of patents granted to developing countries' residents in the total number of patents granted in the United States over the period 1983 to 1988 was only 1 1/4 per cent (based on data from United States Patent and Trademark Office. See Annex 1).

10/ The role of technological change in contributing to economic growth has been empirically demonstrated within the framework of growth accounting. Thus, Solow (1957) has shown that during the first half of this century in the United States about seven eighths of total output increase was related to technical change. Further works confirmed the importance of technical change and tried to decompose the residual (Denison (1962)).

11/ Since Leontief's (1953) provocative findings there have been numerous contributions which have led to a gradual relaxation of Hekscher and Ohlin's original assumption. Instead of explaining trade composition on the basis of homogeneous labour and capital endowments, increasing emphasis has been put on technology variables. Thus, the technology-gap model (Posner (1961)) and the product cycle theory (Hirsch (1965) and Vernon (1966)) as well as subsequent refinements attempt to take into account international differences in the generation, diffusion and adaptation of innovations. Despite these efforts, it has proven difficult to empirically demonstrate the role of technology in trade at the aggregate level.

12/ For a review see Nelson (1981) and Grillichs (1988) and for particular problems within developing countries see Fagerberg (1981) and Chenery (1986).

13/ Enos and Park (1987) have shown how technological learning in Korean industries is reflected in levels of capacity utilization and productivity changes.

14/ As Pack (1988) argues, initially low input ratios might lead to unwarranted conclusions on the importance of technical progress even if the economy achieves a growth of TFP which exceeds that of the change in world best practice.

15/ See Balassa (1977) for a review and Syraquin/Urata (1986) for refined methods of estimating elasticities of capital and labour.

16/ For example, the level of aggregation used by OECD is that of the international surveys on personnel and expenditure devoted to R & D. OECD (1986).

17/ The average or total R & D intensity of industrial output is defined also by the same ratio but is usually obtained as the average of the individual industry R & D intensities weighted by each industry's share in total industrial output.

18/ The R & D intensity of the different industries has been calculated for 11 reference countries taken together as an area. OECD (1986).

19/ See e.g. Kelly (1977), Walker (1979), OECD (1986), UNCTAD (1987).

20/ Industries which are at the boundary of a group may move to another category depending on the year used as a benchmark.

Annex I

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Annex II

International Statistical Yearbooks

ILO, Yearbook of Labour Statistics

IMF, Balance-of-Payments Statistics

OECD, Geographical Distribution of Financial Flows to Developing Countries
Main Science and Technology Indicators

United Nations, International Trade Statistics Yearbook

United Nations, Yearbook of Industrial Statistics

UNCTAD, Handbook of International Trade and Development Statistics

UNESCO, Statistical Yearbook

United States (United States Patent and Trademark Office), Patenting Trends in the United States - State Country Report 1963-1987

WIPO, Industrial Property Statistics

World Bank, World Development Report

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